ASSESSMENT OF RENAL FUNCTION IN HYPERTENSIVE PATIENTS ATTENDING THOMAS ADEWUMI UNIVERSITY TEACHING HOSPITAL, OMUARAN

By

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(21/05BLL004)

A PROJECT SUBMITTED TO THE DEPARTMENT OF MEDICAL LABORATORY SCIENCE, FACULTY OF BASIC MEDICAL AND HEALTHSCIENCES, THOMAS ADEWUMI UNIVERSITY, OKO, KWARA STATE,
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ABSTRACT

Hypertension, characterized by persistently elevated blood pressure (systolic ≥140 mmHg or diastolic ≥90 mmHg), is a prevalent non-communicable disease and significant public health issue in Nigeria. This prospective case-control study assessed renal function and electrolyte profiles in hypertensive patients attending Thomas Adewumi University Teaching Hospital, Omu-Aran, Kwara State. Conducted over four months (April–July 2025), the study involved randomly selected hypertensive and age-matched non-hypertensive individuals. Key parameters measured included blood pressure, serum creatinine, urea, estimated glomerular filtration rate (eGFR), and electrolyte levels using standard methods as described. Results showed significantly higher mean systolic (199 ± 35 mmHg vs. 114 ± 8 mmHg; $p < 0.001$) and diastolic blood pressures (128 ± 20 mmHg vs. 72 ± 6 mmHg; $p < 0.001$) in hypertensive patients compared to controls. Age and anthropometric measures (BMI, waist circumference) did not differ significantly between groups. Serum sodium levels were comparable ($p = 0.188$), but serum potassium was significantly elevated in hypertensives (4.21 ± 0.16 mmol/L vs. 3.40 ± 0.009 mmol/L; $p = 0.003$). These findings suggest an association between hypertension and altered potassium homeostasis, which may impact renal function. In conclusion, the study elucidates the complex interactions among hypertension, renal function, and electrolyte imbalance, emphasizing the need for early monitoring and integrated management to prevent renal complications in hypertensive patients. Future longitudinal research accounting for medication, sex, and comorbidities is advised to further characterize hypertension-induced renal dysfunction

DECLARATION

I, Anifowose Tofunmi Mercy hereby declare that this research work "Assessment of Renal Function in Hypertensive Patients Attending Thomas Adewumi University

Teaching Hospital, Omuaran" this is my original project work and has not been previously submitted elsewhere or in this University for the award of a degree.

06-08-2025

…… ……

Anifowose Tofunmi Mercy Date

CERTIFICATION

I declare that this project report is my original work and has not been previously submitted to any other institution of higher learning.

I further certify that all sources cited or quoted are duly acknowledged by means of comprehensive list of references.

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DEDICATION

This project work is dedicated to Almighty God who has helped me thus far, to my beloved mother for her unwavering supports, to everyone who has made an impact in my academics especially Engineer Jaiyeola Abefe Akinola, Dr Emmanuel Olayinka Olayonu, Pastor Tobi Anifowose. To all the Medical Laboratory Scientists who are selflessly researching and working hard, even out of their comfort zones to diverse health challenges such as hypertension.

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ABBREVIATIONS AND THEIR MEANINGS

1. ADE: Angiotensin-converting enzyme
2. ANP: Atrial natriuretic peptide
3. BP: Blood pressure
4. BMI: Body mass index
5. BNP: Brain natriuretic peptide
6. BUN: Blood urea nitrogen
7. CKD: Chronic kidney disease
8 . CVD: Cardiovascular diseases
9. ESRD: End-stage renal disease
10. EGF: Epidermal growth factor
11. EGFR: Estimated glomerular filtration rate
12. FSGS: Focal-segmental-glomerular sclerosis
13. DASH: Dietary approaches to stop hypertension
14. DBP: Diastolic blood pressure
15. MAPKs: Mitogen-activated protein kinases
16. RAAS: Renin-angiotensin-aldosterone system
17. SNS: Sympathetic nervous system
18. SBP: Systolic blood pressure

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Hypertension is commonly referred to as high blood pressure and is one of the most recent prevalent non-communicable diseases worldwide (Dzau and Balatbat, 2019; Simatupang *et al*., 2021). It is characterized by sustained elevated blood pressure levels, typically defined as a systolic blood pressure of ≥140 mmHg or a diastolic pressure of ≥90 mmHg (Rajmohan *et al*., 2020; Charchar *et al*., 2023). The burden of hypertension is immense, affecting approximately 1.39 billion people globally (31.1% adults), with the prevalence continuing to rise, especially in low- and middle-income countries like Nigeria with 80% burden (Mills *et al*., 2020). According to the World Health Organization (WHO), hypertension is responsible for 7.6 million deaths annually, accounting for about 12.8% of all deaths globally (Dzau and Balatbat, 2019; Zhou *et al*., 2021).

In Nigeria, hypertension is increasingly recognized as a major public health concern (Akinlua *et al*., 2015). A systematic review of hypertension prevalence in Nigeria revealed 0.1% in Children to about 30-47.2% of adults have hypertension, with urban populations showing higher prevalence rates than rural areas (Adeloye *et al*., 2015; Ezejimofor *et al*., 2018). In Kwara State, the age-adjusted prevalence of hypertension was found to be 24% in rural areas (Olarenwaju *et al*., 2020). Contributing factors include rapid urbanization, changes in dietary habits, increasing levels of obesity, and reduced physical activity (Hasnani *et al*., 2023; Zambrano *et al*., 2023).

Hypertension is a multifactorial and polygenic condition influenced by genetic predispositions, environmental factors, and lifestyle habits (Pratamawati *et al*., 2023). The pathophysiology of hypertension involves complex interactions between the

cardiovascular, renal, and neuroendocrine systems (Hasnani *et al*., 2023). One of the key mechanisms in hypertension development is the dysregulation of the renin-angiotensin-aldosterone system (RAAS), which controls blood volume and systemic vascular resistance, both essential in maintaining normal blood pressure (Zambrano *et al*., 2023). When the RAAS system becomes overactive, it leads to increased vasoconstriction and sodium retention, causing blood pressure to rise (Ghatage *et al*., 2021). Additionally, abnormalities in vascular endothelial function, including reduced production of vasodilators such as nitric oxide, contribute to increased vascular resistance (Munoz-Durango *et al*., 2016; Ghatage *et al*., 2021). Over time, persistently elevated blood pressure exerts excess pressure on the blood vessels, causing damage to various organs, including the heart, brain, and kidneys (Li *et al*., 2018).

The kidneys play a crucial role in regulating blood pressure by controlling fluid balance, salt retention, and the production of hormones like renin, which regulate blood pressure (Yu *et al*., 2020). Hypertension and kidney disease are closely interlinked, creating a vicious cycle in which uncontrolled blood pressure progressively damages renal function, and worsening kidney function further exacerbates hypertension (Yu *et al*., 2020). Chronic hypertension leads to kidney damage by affecting the small blood vessels within the kidneys. One of the primary mechanisms of injury is glomerulosclerosis, a condition characterized by the scarring of the glomeruli, which are the tiny filtration units within the kidneys (Qaddumi and Jose, 2021). This reduces the kidney's ability to filter waste products from the blood effectively (Abene *et al*., 2020). Over time, this damage can progress to chronic kidney disease (CKD) (Nwachukwu *et al*., 2016). In Nigeria, a significant proportion of hypertensive patients eventually develop CKD, with many presenting in the later stages of the disease when

treatment options are limited and expensive (Ogunba *et al*., 2023). Unfortunately, routine screening for renal dysfunction in hypertensive patients is not widespread, especially in resource-limited settings like Thomas Adewumi University Teaching Hospital community. Many hypertensive individuals are unaware of the extent of their kidney damage until they experience end-stage renal disease (ESRD), which requires dialysis or kidney transplantation (Nwachukwu *et al*., 2016). This makes early detection of kidney dysfunction vital in preventing the progression to ESRD. This study aims to fill this gap by assessing renal function in hypertensive patients at the university.

1.2 STATEMENT OF PROBLEM

Hypertension is a significant public health issue and a leading cause of morbidity and mortality worldwide. It is associated with various cardiovascular and renal complications, making it a critical factor in the development of chronic kidney disease (CKD). In Nigeria, the prevalence of hypertension is rapidly increasing, fueled by urbanization, changes in lifestyle, and inadequate healthcare infrastructure. Despite being one of the most preventable causes of kidney disease, hypertension remains poorly managed, with many hypertensive individuals progressing to advanced stages of renal impairment before diagnosis or intervention is made. Kidney damage due to hypertension, often referred to as hypertensive nephropathy, occurs silently over time, leading to irreversible loss of kidney function. The kidneys, which play a crucial role in maintaining blood pressure and filtering waste from the blood, are particularly vulnerable to damage from prolonged elevated blood pressure. If left untreated, hypertensive nephropathy can progress to end-stage renal disease (ESRD), requiring costly treatments such as dialysis or kidney transplantation.

At Thomas Adewumi University Community of Kwara State, Nigeria there is limited research examining the renal health of hypertensive patients, leaving a critical gap in the understanding of how hypertension impacts kidney function within this specific population. Therefore, this study seeks to address these gaps by assessing renal function in hypertensive patients attending Thomas Adewumi University Teaching Hospital by investigating key renal markers such as serum creatinine, blood urea nitrogen (BUN), and estimated glomerular filtration rate (eGFR), the study aim to provide valuable insights into the prevalence and extent of kidney dysfunction in hypertensive individuals within this community. Additionally, it seeks to establish correlations between blood pressure levels and renal function, which can further inform the clinical management of hypertension and reduce the risk of renal complications.

1.3 JUSTIFICATION OF THE STUDY

The assessment of renal function in hypertensive patients in Nigeria is crucial for several reasons. Early detection and prevention of renal dysfunction can significantly reduce the progression of chronic kidney disease (CKD), which is prevalent among hypertensive individuals (Ekun *et al*., 2020; Alhassan *et al*., 2022). This study also aims to contribute to localized healthcare data, providing valuable insights specific to the Nigerian population, which can help tailor more effective healthcare strategies (Ekun *et al*., 2020). By identifying and managing renal dysfunction early, long-term healthcare costs associated with advanced CKD can be reduced, benefiting both patients and the healthcare system. Additionally, enhancing hypertension management through regular renal function assessments can improve overall patient outcomes, reducing the incidence of hypertension-related complications (Abene *et al*., 2020).

Addressing the high burden of hypertension-related CKD in Nigeria is essential, as it remains a significant public health challenge (Abene *et al*., 2020). This study will also foster health awareness in the Oko community, encouraging proactive health behaviors and regular check-ups. By contributing to future research, the findings can support the development of health policies aimed at improving renal health and hypertension management. Furthermore, enhancing healthcare infrastructure in the Oko community through this study can lead to better healthcare delivery and patient care. Overall, this research is vital for improving patient outcomes and supporting the development of effective health policies and infrastructure in Oko Community, Irepodun Local Government Area. It is therefore, imperative that this research study be carried out.

1.4 AIM OF THE STUDY

To assess Renal function in Hypertensive patients at Thomas Adewumi University Teaching Hospital, Omu-Aran

1.5 SPECIFIC OBJECTIVES

1. To determine the Blood pressure level of hypertensive patients at Thomas Adewumi University Teaching Hospital

2. To measure estimated glomerular filtration rate (eGFR), serum creatinine and urea in hypertensive patients.

3. To compare renal function parameters between hypertensive and non-hypertensive individuals.

4. To correlate blood pressure levels and renal function parameters in hypertensive patients.

1.6 RESEARCH QUESTIONS

1. What is the blood pressure level of Hypertensive patients attending Thomas Adewumi University Teaching Hospital?

2. What is the status of renal function in hypertensive patients in Thomas Adewumi University Teaching Hospital?

3. Is there any difference in the renal parameters of hypertensive and non-hypertensive individuals?

4. How does blood pressure level correlate with renal function parameters?

1.7 RESEARCH HYPOTHESIS

1.7.1 NULL HYPOTHESIS

There is no association between blood pressure level and renal function parameter of hypertensive patients attending Thomas Adewumi University Teaching Hospital?

There's no statistically significant difference between Renal Function parameters of Hypertensive and Non-hypertensive patients.

1.7.2 ALTERNATE HYPOTHESIS

There is association between blood pressure level and renal function parameter of hypertensive patients attending Thomas Adewumi University Teaching Hospital?

There's statistically significant difference between Renal Function parameters of Hypertensive and Non-hypertensive patients.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HYPERTENSION

2.1.1 DEFINITION AND BRIEF BACKGROUND

Hypertension (also called primary hypertension or idiopathic hypertension) is characterized by persistently high blood pressure (BP) in the systemic arteries (Javed *et al*., 2018). BP is commonly expressed as the ratio of the systolic BP (that is, the pressure that the blood exerts on the arterial walls when the heart contracts) and the diastolic BP (the pressure when the heart relaxes). The BP thresholds that define hypertension depend on the measurement method (Table 1) (Oprial *et al*., 2018). About 90–95% of patients with hypertension have a highly heterogeneous primary hypertension with a multifactorial aetiology arising from interaction between genetic and environment factors (Kokubo *et al*., 2019). A positive family history is a frequent occurrence in patients with hypertension, with the heritability estimated to be between 35% and 50% in the majority of studies (Warren *et al*., 2017). Several rare, monogenic forms of hypertension have been described (for example, Liddle syndrome, glucocorticoid-remediable aldosteronism (a mineralocorticoid excess state) and conditions due to mutations in *PDE3A* (which encodes cGMP-inhibited 3′,5′-cyclic phosphodiesterase A), in which a single gene mutation fully explains the pathogenesis of hypertension and indicates the best treatment modality (Maass *et al*., 2015). Hypertension is the most common preventable risk factor for cardiovascular degeneration and is the leading single contributor to all cause mortality and disability worldwide (Forouzanfar, 2016). The relationship between BP and the increased risk of cardiovascular diseases (CVD) is graded and continuous, starting at BPs as low as

115/75mmHg, well within what is considered to be the normotensive range (Oprial *et al*., 2018).

Table 1: Classification of office blood pressure by class or grade, mm Hg

	Systolic and diastolic blood pressure, mm Hg
American College of Cardiology–American Heart Association (Whelton *et al*., 2018)	
Normal	<120 and <80
Increased	120-129 and <80
Stage 1	130-139 or 80-89
Stage 2	≥140 or ≥90
European Society of Cardiology–European Society of Hypertension (William *et al*., 2018)	
Optimal	<120 and <80
Normal	120-129 or 80-84, or both
High-normal	130-139 or 85-89, or both
Stage 1	140-159 or 90-99, or both
Stage 2	160-179 and 100-109, or both
Stage 3	≥180 and ≥100, or both
Isolated systolic hypertension	≥140 and <90
International Society of Hypertension (Unger *et al*., 2020)	
Normal	<130 and <85
High-normal	130-139 or 85-89, or both
Grade 1 hypertension	140-159 and 90-99
Grade 2 hypertension	≥160 and ≥100 or both

2.1.2 GLOBAL EPIDEMIOLOGY AND DISEASE BURDEN

Globally, 3.5 billion adults have non-optimal systolic BP levels (that is, >110–115mmHg), and 874 million adults have a systolic BP of ≥140mmHg. Thus, approximately one in four adults has hypertension (Forouzanfar *et al*., 2017). Between 1990 and 2015, there was a 43% increase in the total global number of healthy life years lost to non-optimal BP, driven by population increase, population ageing and a 10% increase in the age-standardized prevalence of hypertension (Forouzanfar *et al*., 2017). The Global Burden of Disease study has shown that non-optimal BP continues to be the largest single risk factor contributing to the global burden of disease and to global all-cause mortality (Forouzanfar, 2016). In a systematic analysis done for the Global Burden of Disease Study 2017, high systolic blood pressure (SBP) was the leading risk factor for mortality (10·4 million deaths) and disability-adjusted life-years (218 million) (Oparil *et al*., 2018). In a study including 8·69 million participants from 154 countries, it was estimated that between 1990 and 2015, the number of participants with an SBP of at least 110–115 mm Hg increased from 73·1% to 81·3%, and those with an SBP of at least 140 mm Hg increased from 17·3% to 20·5% (Olsen *et al*., 2016). Additionally, the estimated rate of annual deaths associated with an SBP of at least 110–115 mm Hg increased by 7·1% from 1356 per million, and deaths associated with an SBP of at least 140 mm Hg increased by 8·6% from 979 per million (Oparil *et al*., 2018).

According to the 2016 May Measurement Month campaign initiated by the International Society of Hypertension (ISH), involving more than 1·5 million individuals screened from 92 countries, 32·0% had never had their blood pressure measured and 34·0% had been diagnosed with hypertension, among whom 58·7% were aware that they had hypertension and 54·7% were on antihypertensive medications

(Surendran *et al*., 2016). In patients with hypertension, 31·7% had blood pressure readings below 140/90 mm Hg and 23·3% below 130/80 mm Hg. Of patients on at least one anti-hypertensive, 57·8% had blood pressure readings below 140/90 mm Hg and 28·9% below 130/80 mm Hg (Sofie *et al*., 2021). Of patients taking anti-hypertensive medications, half were single-drug users. Since May, 2017, more than 4·2 million participants had their blood pressure measured and almost 1 million adults with hypertension were untreated or undertreated (Sofie *et al*., 2021).

In the African population, a systematic review and meta-analysis of data from 25 studies showed a pooled prevalence of 5·5% in children and adolescents with elevated blood pressure (≥95th percentile) and of 12·7% in children and adolescents with slightly elevated blood pressure (≥90th percentile and <95th percentile) (Noubiap *et al*., 2017). Increased body-mass index was largely associated with prevalence of elevated blood pressure, which was six times higher in children and adolescents (aged 2–19 years) with obesity than in age-matched individuals without obesity. The meta-analysis also found that elevated blood pressure was more pervasive in rural areas than in urban areas; however, no differences in prevalence were observed between boys and girls (Noubiap *et al*., 2017). Another study showed that the prevalence of hypertension is higher in people of African origin than in those of European origin (Hardy *et al*., 2017).

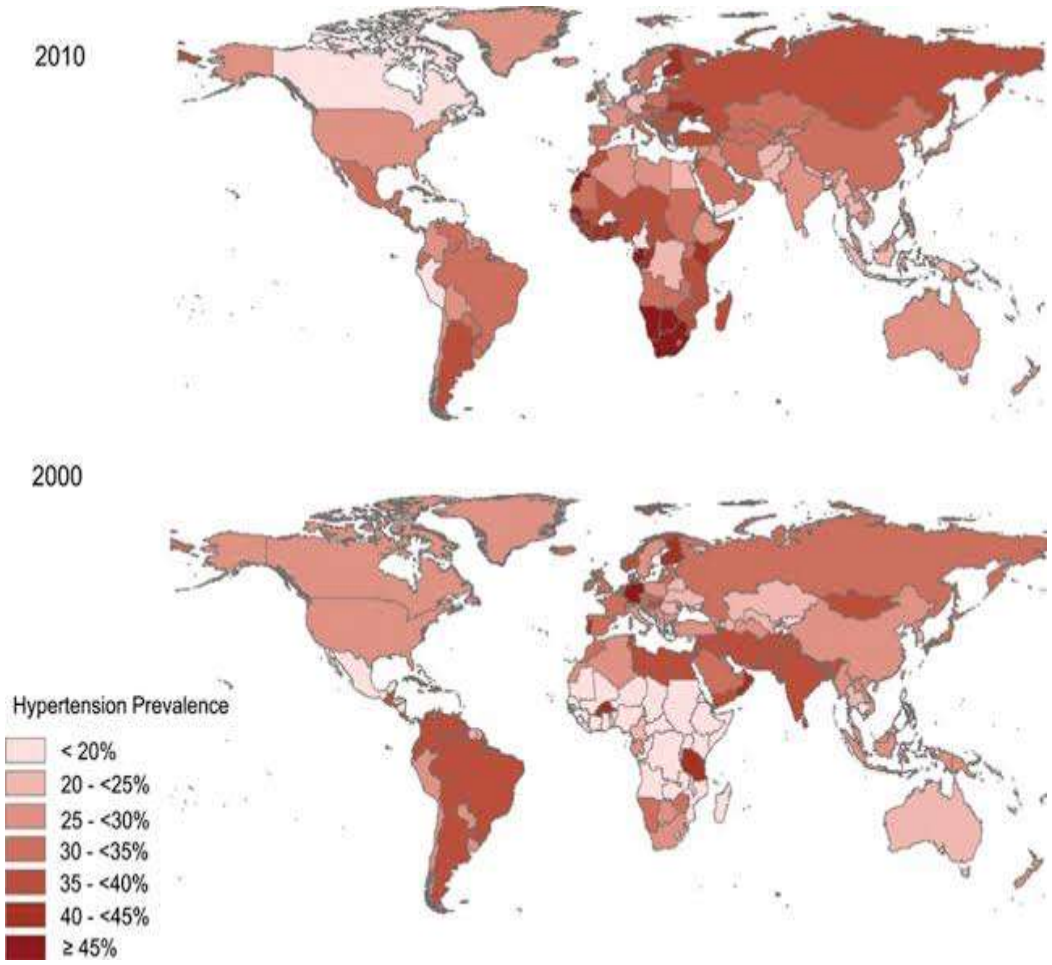


Figure 1: Global prevalence of Hypertension (Adapted from Mills *et al*., 2016)

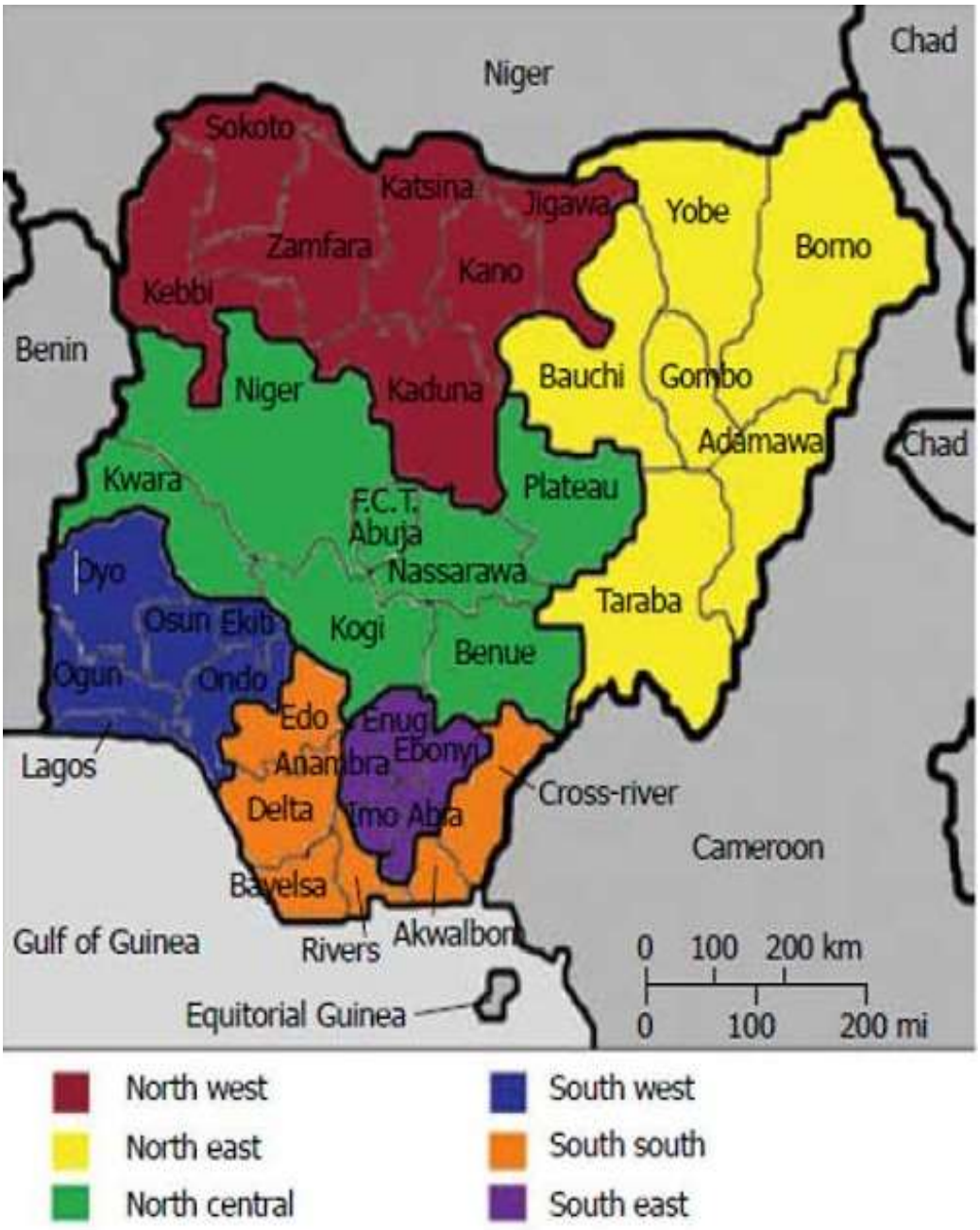


Figure 2: Prevalence of Hypertension in Nigeria (Adapted from Akinlua *et al*., 2015)

2.1.3 ETIOLOGY OF HYPERTENSION

The cause of hypertension is multifactorial in nature, with environment, genetics, and social determinants having the potential to contribute to its development (Carey *et al*., 2018). A better understanding of the interplay between these components has continued to unfold (Taddei *et al*., 2018). Researchers have discovered that there's a correlated relationship between the etiological factors of hypertension in adults with blood pressure elevations in youth (Pratamawati *et al*., 2023). Intrauterine malnutrition, family history of hypertension, obesity, particularly excess abdominal fat, insulin resistance, high dietary sodium intakes, low dietary intakes of calcium, potassium and magnesium, physical inactivity, high alcohol intakes, tobacco use, drug use (e.g., cocaine, ecstasy, anabolic steroids), emotional stress, diet pill use, oral contraceptives are the factors associated with development of hypertension (Haikerwal *et al*., 2020; Kanda *et al*., 2020). An inadequate supply of nutrients may program changes in foetal structure and metabolism, increasing the risk of hypertension and other diseases in later life (Oparil *et al*., 2018). Hyperinsulineamia and insulin resistance are also associated with the development of hypertension which leads to many problems. The elevated plasma insulin levels may cause sodium sensitivity (Munzel *et al*., 2017). Adequate dietary potassium, calcium, and magnesium intakes have been associated with lower blood pressure in youth. Potassium and calcium intakes are below recommended levels, particularly in adolescent females, while median intakes of phosphorus and protein, which promote calcium loss, are high (Munzel *et al*., 2017). Lack of physical activity may increase the risk of developing hypertension by 20-50% (Javed *et al*., 2018).

2.1.4 RISK FACTORS OF HYPERTENSION

The various risk factors which can lead to hypertension are,

Smoking

Cigarette smoking, a known risk factor for the development of hypertension and other cardiovascular diseases like myocardial infarction, stroke, and even sudden coronary death (Freitas and Alvim, 2017). When a person gets exposed to tobacco smoke and active smoking, the number of segments of intracranial arteries increases with mixed atherosclerotic plaques (Gac *et al*., 2017). Thus it is associated with the deterioration of health status (Papathanasiou *et al*., 2015). On exposure to cigarette smoke ,there is a reduction in the nitric oxide which is a vasodilator and initiates vascular damaging thus leads to increased adhesion of platelets and macrophages which in turn enhance the inflammatory response. It also leads to tissue damage and its remodeling and thus structure of the vessel changes (Kim, 2024). Passive smoking is greatly associated with the prevalence of hypertension (Wu *et al*., 2017).

Stress

The stress is associated with high blood pressure (Steptoe *et al*., 2016). Due to an increase in stress level, the sympathetic nervous system activates and hence results in increased blood pressure (Ziegler and Milic, 2017). By blocking the orexin receptor (present in the hypothalamic defense region), blood pressure can be reduced because on its blocking, cardiovascular system does not respond to stress (Uruski *et al*., 2025).

Salt

Another risk factor is salt sensitivity which is an environmental factor that has received the greatest attention. Approximately one third of the hypertensive population is responsive to sodium intake (Rust and Ekmekcioglu, 2016). The increased sodium ion concentration stimulates ADH and thirst mechanisms, leading to increased reabsorption

of water in the kidneys, concentrated urine, and thirst with higher intake of water (Javed *et al*., 2018). Also, the water movement between cells and the interstitium plays a minor role compared to this. The relationship between sodium intake and blood pressure is controversial. Reducing sodium intake does reduce blood pressure, but the magnitude of the effect is insufficient to recommend a general reduction in salt intake (Oparil *et al*., 2018). Renin elevation is another risk factor. Renin is an enzyme secreted by the juxtaglomerular apparatus of the kidney and linked with aldosterone in a negative feedback loop (Mancia *et al*., 2020). In consequence, some hypertensive patients have been defined as having low-renin and others as having hypertension. Low-renin hypertension is more common in African Americans than white Americans, and may explain why African Americans tend to respond better to diuretic therapy than drugs that interfere with the Renin angiotensin system (Mancia *et al*., 2020). High renin levels predispose to hypertension by causing sodium retention through the following mechanism: Increased renin Increased angiotensin II Increased vasoconstriction, thirst/ADH and aldosterone →Increased sodium reabsorption in the kidneys (DCT and CD) Increased blood pressure (Rust and Ekmekcioglu, 2016). Hypertension can also be caused by Insulin resistance and or hyperinsulinemia, which are components of syndrome X, or the metabolic syndrome. Also, some authorities claim that potassium might both prevent and treat hypertension (Sofie *et al*., 2021). Several studies have shown that hypertensive patients and their children handle salt differently. It is suggested that due to the presence of a sodium transport inhibitor, leucocytes of hypertensive patients are found to have a reduced sodium pump activity (Ertuglu *et al*., 2021; Kawarazaki and Fujita, 2021; Sofie *et al*., 2021). This results in increased intracellular sodium leading to high intracellular calcium which is responsible for increased vascular tone. Due to abnormal sodium handling, renal sodium excretion is

affected which leads to increase in extracellular fluid volume, an increased venous return and increased cardiac output (Oparil *et al*., 2018). Autoregulation to achieve tissue perfusion leads to vasoconstriction and raised peripheral vascular resistance. Salt restriction interrupts pathophysiologic chain of events by lowering extracellular fluid volume and lowers blood pressure similar to diuretic therapy (Javed *et al*., 2018).

Obesity

Obesity can increase the risk of hypertension to fivefold as compared with normal weight, and up to two-thirds of hypertension cases can be attributed to excess weight. More than 85% of cases occur in those with a Body mass index greater than 25 (Oparil *et al*., 2018). The hypertension and diabetes which are more common in adults, are now also becoming popular in obese children than children bearing normal weight (Jia and Sowers, 2021). The most significant cause of hypertension is obesity in patients suffering from hypertension (do Carno *et al*., 2016). The factors which indicates the relation between the HTN and obesity are oxidative stress and inflammation, vascular injury, impaired autonomic nervous system (Susic and Varagic, 2017).

Alcohol

Excessive alcohol intake also leads to hypertension. Various mechanisms were proposed but still its mechanism is not clear. Several possible mechanisms are oxidative stress, vascular injury, less production of nitric oxide, impaired baro-receptors, stimulation of RAS system (Sievers and Eckardt, 2019).

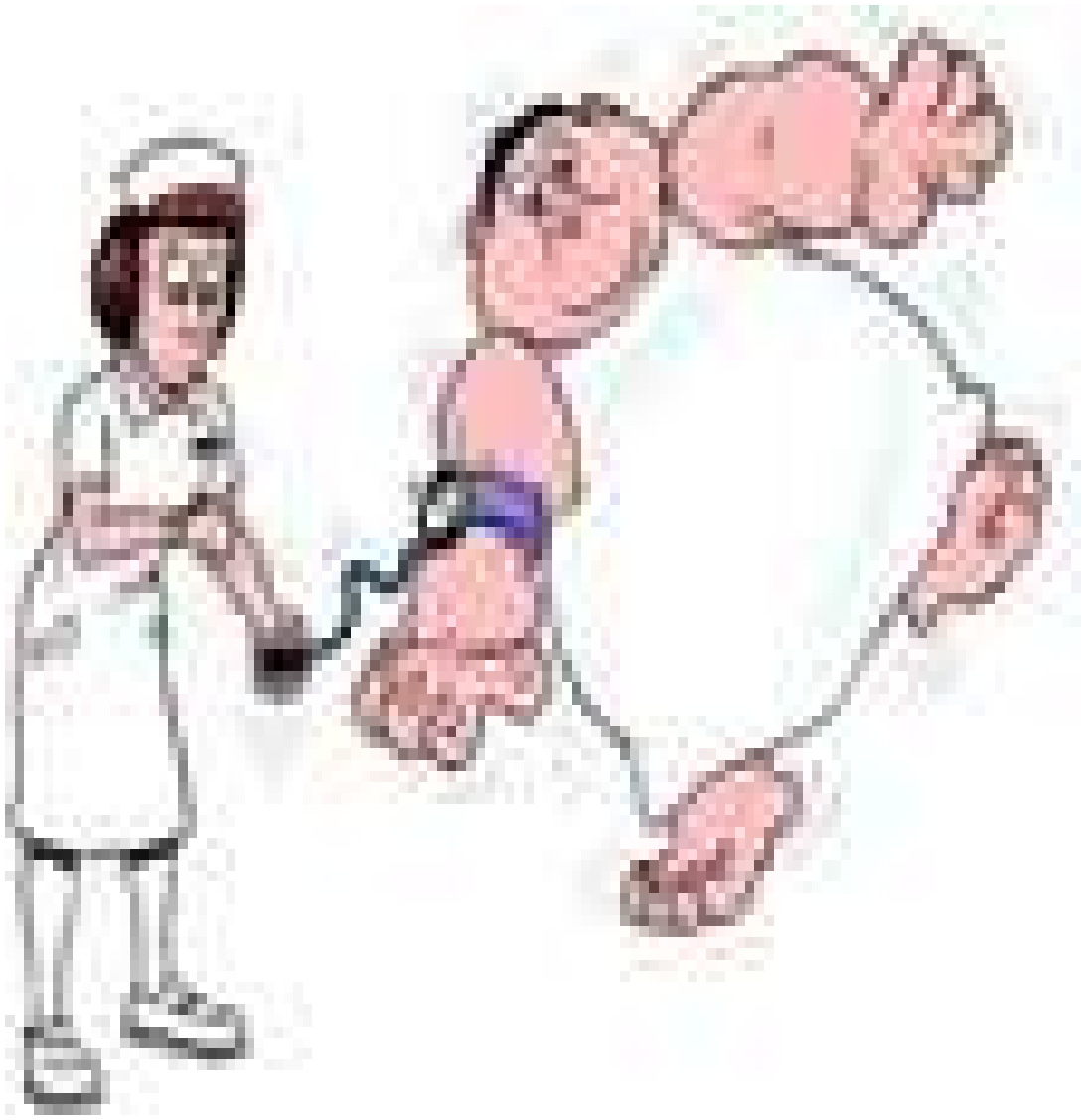
Family History and Race

Having a personal family history of hypertension increases the likelihood that an individual develops hypertension (Sulaica *et al*., 2020). Hypertension is four times more common in black than white people, accelerates more rapidly and is often more severe with higher mortality in black patients (Ojji *et al*., 2019).

(a) Excessive salt intake

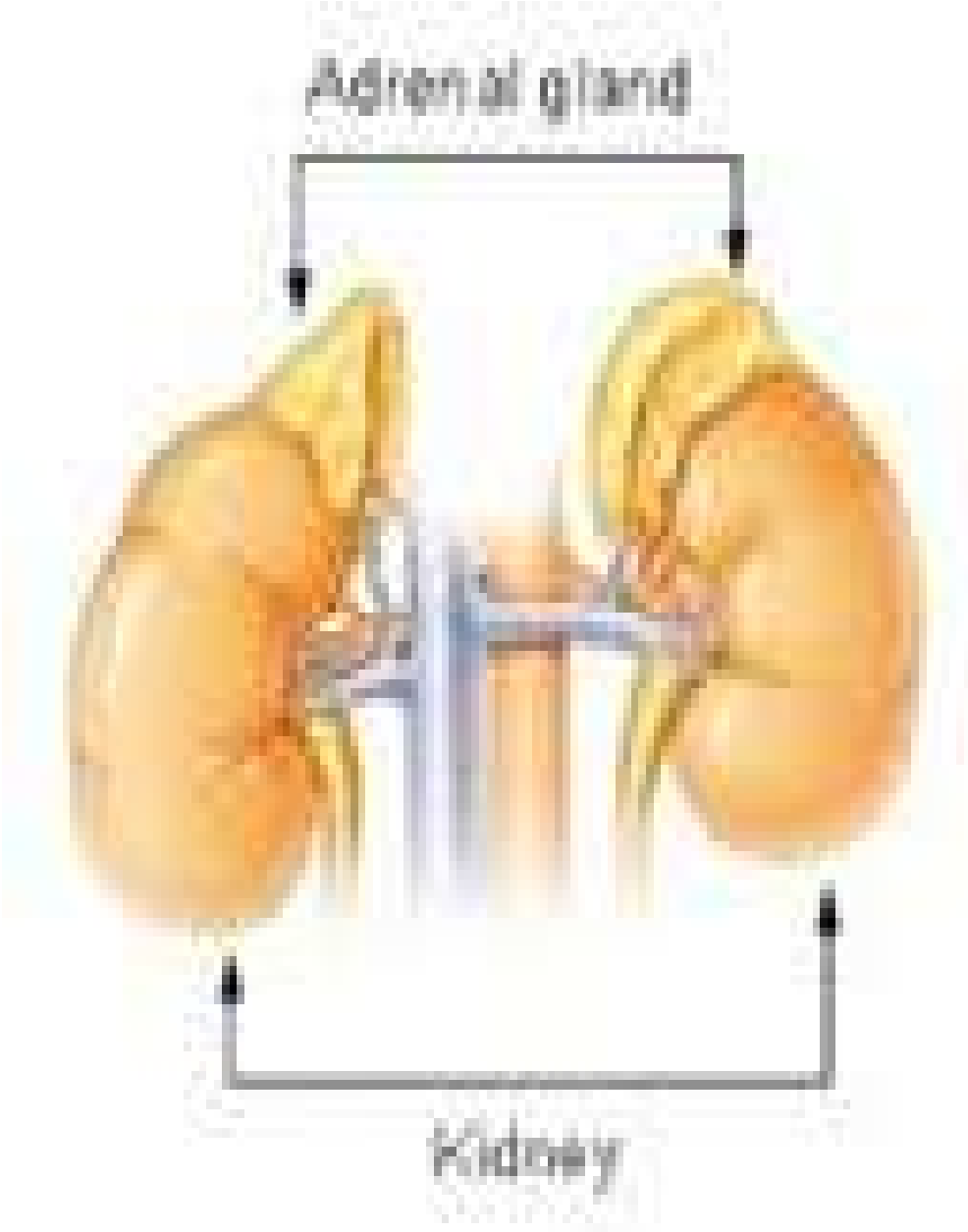
(b) Genetic problems

(c) Stressful life volume

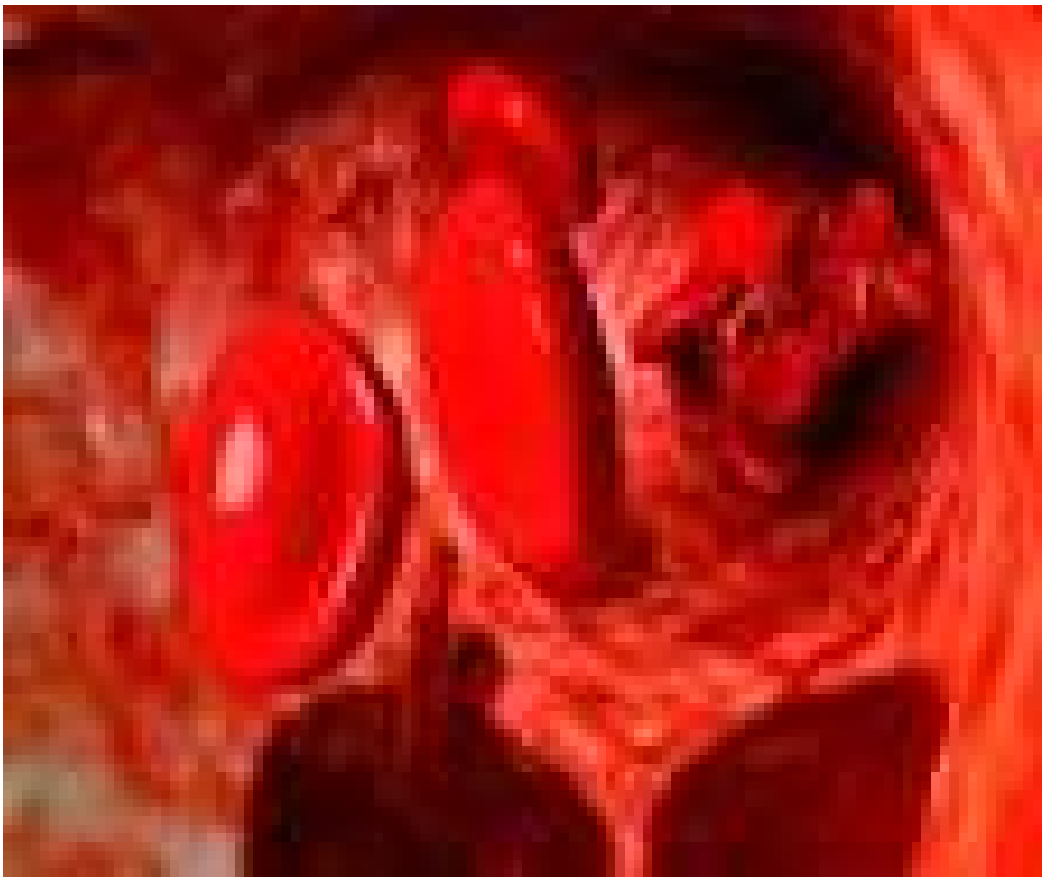


(d) Obesity

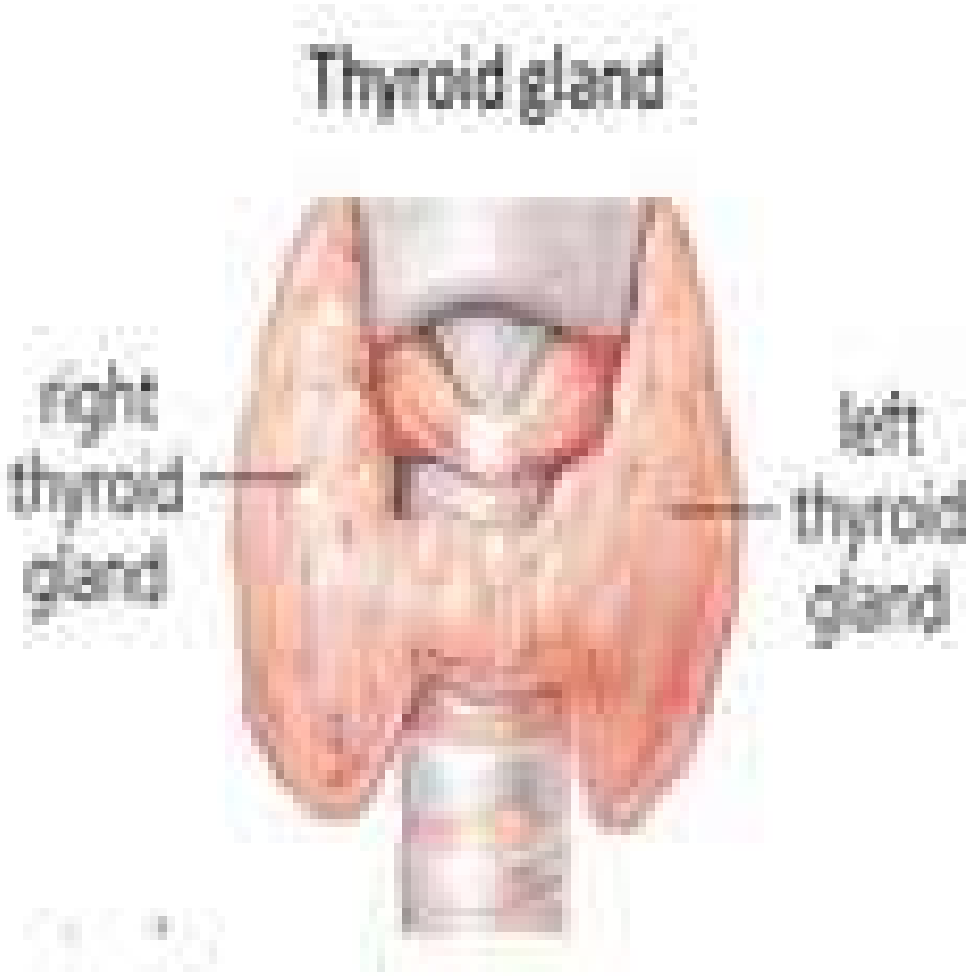
(e) Pregnancy



(f) Kidney/adrenal problem

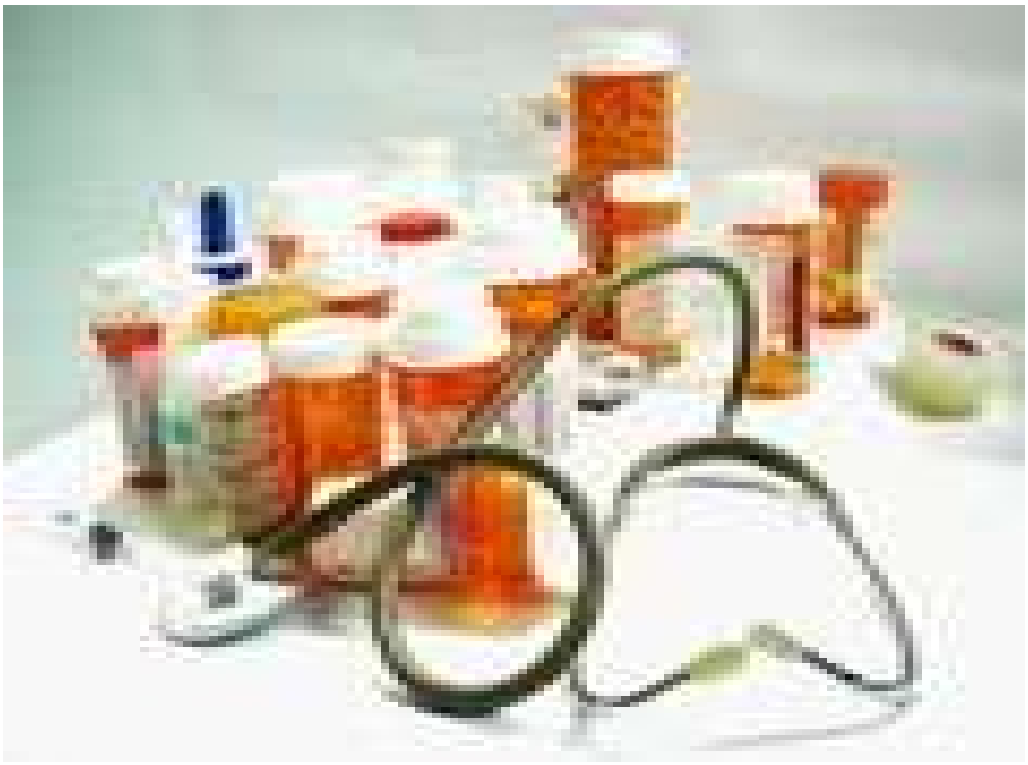


(g)Blood Volume



(h) Thyroid disorder

(i) Sympathetic nervous system



(j) Drugs

Figure 3: a-j showing various risk factors for Hypertension (Adapted from Javed *et al.*, 2018)

2.1.5 PATHOPHYSIOLOGY OF HYPERTENSION

Blood pressure regulation

Several parameters of the cardiovascular system determine Blood pressure (BP) this includes blood volume and cardiac output (the amount of blood pumped by the heart per minute), as well as the balance of arterial tone (Peripheral resistance), which is affected by both intravascular volume and neurohumoral systems (Javed *et al*., 2018; Oparil *et al*., 2018). The complex interplay of various elements of an integrated neurohumoral system that includes the natriuretic peptides and endothelium, sympathetic nervous system (SNS), renin–angiotensin–aldosterone system (RAAS) and the immune system maintains the physiological BP level (figure 4) (Javed *et al*., 2018). Once any of this integrated neurohumoral component system factors malfunction that involves BP control directly or indirectly the mean BP increases, and over time results in target-organ damage (for example, left ventricular hypertrophy, cardiovascular disease (CVD) and chronic kidney disease (CKD) outcomes (Hall and Hall, 2018). The pathophysiological mechanisms responsible for hypertension are complex and act on a genetic background. Primary hypertension involves multiple types of genes; some allelic variants of several genes are associated with an increased risk of developing primary hypertension and are linked in almost all cases to a positive family history (Meng *et al*., 2015; Cabandugama *et al*., 2017). This genetic predisposition, along with a host of environmental factors, such as high sodium intake, poor sleep quality or sleep apnoea, excess alcohol intake and high mental stress, contributes to the development of cardiac output and peripheral resistance (Smulyan *et al*., 2016).

Sodium homeostasis regulation

Blood volume is crucially regulated by Sodium that is sodium plays a vital role in blood volume regulation. Therefore, in the presence of high serum sodium concentration fluid (water) retention occurs thereby increasing Blood pressure and consequently blood volume (Brouwers *et al*., 2021). it is important to know that in a normotensive individual who consumes dietary sodium, compensatory hemodynamic changes occur to maintain constant BP. These changes also include reduction in renal and peripheral vascular resistance and increased production of nitric oxide (NO, a vasodilator) from the endothelium (Javed *et al*., 2018). However, if the effect of NO is impaired or absent, an increase in BP occurs (Kim, 2024). Endothelial dysfunction is a risk factor for the development of salt sensitivity and subsequent hypertension (Oparin *et al*., 2018). Salt sensitivity is defined as a marked elevation in BP following a sodium load of ≥5g and is characterized by an elevation of systolic BP of at least 10mmHg within a few hours of ingestion (Oparin *et al*., 2018). Individuals who are salt-sensitive have underlying endothelial dysfunction due to genetic or environmental influences. In response to a high salt load, these individuals generally manifest overproduction of transforming growth factor-β (TGF-β), which increases the risk of fibrosis, and oxidative stress and have limited bioavailable NO. Chronic high salt ingestion can result in endothelial dysfunction, even in individuals who are not salt-sensitive and also affects the gut microbiota, with resultant changes that contribute to increased salt sensitivity and the development of hypertension (Wilck *et al*., 2017). High salt intake also seems to drive autoimmunity by inducing T helper 17 (TH17) cells (Wilck *et al*., 2017). High salt intake in mice has been shown to deplete *Lactobacillus murinus* in the gut microbiota. Treatment of mice with *L. murinus* prevented salt-induced exacerbation of salt-sensitive hypertension by modulating TH17 cells (Wilck *et al*., 2017). In line with these

findings, a moderate high-salt challenge in a pilot study in humans reduced intestinal survival of *Lactobacillus* spp., increased the number of TH17 cells and increased BP31. Thus, the gut microbiota seems to contribute to salt sensitivity of BP and the pathogenesis of hypertension (Baker *et al*., 2017).

Renin–angiotensin–aldosterone system (RAAS)

The RAAS has various effects on BP regulation, mediating sodium retention, pressure natriuresis leading to decreased sodium reabsorption and increased sodium excretion, salt sensitivity, vasoconstriction, endothelial dysfunction, and vascular injury and hence, its central role in the pathogenesis of hypertension (Ramalingam *et al*., 2017; Hall and Hall, 2018) (figure 4). The RAAS plays its most crucial in the regulation of pressure–volume homeostasis in the kidney where it maintains perfusion in volume-depleted states and is suppressed in volume-expanded (fluid overload) conditions. It is also known to be present at the cellular level of many organs (Munoz-Durango *et al*., 2016). Renin and its precursor, pro-renin, are synthesized and stored in the juxtaglomerular cells of the kidney and are released in response to various stimuli (figure 5) (Munoz-Durango *et al*., 2016). The main function of renin is to cleave angiotensinogen to form angiotensin I. Angiotensin-converting enzyme (ACE) cleaves angiotensin I to form angiotensin II, which is at the center of the pathogenetic role of the RAAS in hypertension (Hall and Hall, 2018) (figure 5).

Angiotensin II enhances sodium reabsorption in the proximal tubule by increasing the activity of the electrogenic sodium bicarbonate cotransporter 1, sodium/hydrogen exchanger 3, and Na+/K+-ATPase and by inducing aldosterone synthesis and release from the adrenal glomerulosa (Javed *et al*., 2018). Endothelial dysfunction and has profibrotic and pro-inflammatory effects, mediated in large part by increased oxidative

stress, resulting in renal, cardiac and vascular injury (Brouwers *et al*., 2021). Angiotensin II is tightly linked to target-organ damage in hypertension via these mechanisms ACE2 has emerged as an important modulator in the pathophysiology of hypertension, CVD and renal disease, owing to its role in metabolizing angiotensin II into angiotensin (1–7) (Singh and Williams, 2017). Angiotensin (1–7) induces systemic and regional vasodilation, diuresis and natriuresis and exerts antiproliferative and antigrowth effects on vascular smooth muscle cells, cardiac myocytes and fibroblasts as well as on glomerular and proximal tubular cells (Nwia *et al*., 2022). Angiotensin (1–7) also has cardio-renal protective effects that are mediated by the proto-oncogene Mas receptor through signalling pathways that include mitogen-activated protein kinases (MAPKs), PI3K–AKT (phosphoinositide 3-kinase–RAC serine/threonine protein kinase), NADPH oxidase, TGFβ1, the epidermal growth factor (EGF) receptor and nuclear factor-κB (NF-κB) activity (Nwia *et al*., 2022). Aldosterone plays a crucial part in hypertension by binding to the mineralocorticoid receptor, it induces non-genomic effects that include activation of the amiloride-sensitive sodium channel, commonly known as the epithelial sodium channel (ENaC), and result in the stimulation of renal sodium reabsorption in the cortical collecting duct (De Silva *et al*., 2021). Aldosterone also has many non-epithelial effects (vascular smooth muscle cell proliferation, vascular extracellular matrix deposition, vascular remodelling, fibrosis and increased oxidative stress) that contribute to endothelial dysfunction, vasoconstriction and hypertension (Oparil *et al*., 2018).

Natriuretic peptides

Atrial natriuretic peptide (ANP) and brain natriuretic peptide (BNP) play an important part in salt sensitivity and hypertension (figure 4). They have important natriuretic and vasodilator properties that enable the maintenance of sodium balance and blood

pressure during sodium loading (Kim, 2024). Atrial and ventricular stretch occurs upon administration of a sodium load and this leads to the release of ANP and BNP, respectively with an immediate systemic vasodilation and plasma volume decrease thus loweing the blood pressure (Nwia *et al*., 2022). Natriuretic peptides increase glomerular filtration rate via an increase in efferent arteriolar tone in volume-expanded states and inhibit renal sodium reabsorption through both direct and indirect effects (Nwia *et al*., 2022). Direct effects include decreased activity of Na+/K+-ATPase and the sodium-glucose cotransporter in the proximal tubule and inhibition of the ENaC in the distal nephron. Indirect effects include inhibition of renin and aldosterone release (Javed *et al*., 2018).

Natriuretic peptide deficiency promotes hypertension. Corin (also known as atrial natriuretic peptide converting enzyme) is a serine protease that is largely expressed in the heart and converts the ANP and BNP precursors pro-ANP and pro-BNP to their active forms. Corin deficiency has been associated with volume overload, heart failure and salt-sensitive hypertension (Sievers and Eckardt, 2019). Natriuretic peptide deficiency also predisposes to insulin resistance and type 2 diabetes mellitus. Obesity is associated with natriuretic peptide deficiency, probably through upregulation of the atrial natriuretic peptide receptor 3 in adipose tissue (Oparil *et al*., 2018). Natriuretic peptides have therapeutic potential for the metabolic syndrome — a cluster of conditions (including high BP, high fasting glucose levels, abdominal obesity, high triglycerides and microalbuminuria) that occur together, increasing the risk of CVD and diabetes mellitus (Sievers and Eckardt, 2019).

Endothelium

The endothelium is a major regulator and contributor of vascular tone and salt sensitivity through Nitric Oxide respectively (figure 4) (Oparil *et al*., 2018). Endothelial

cells produce a host of vasoactive substances, of which Nitric oxide is the most important in blood pressure regulation (Liu *et al*., 2024). NO is continuously released by endothelial cells in response to flow-induced shear stress, leading to vascular smooth muscle relaxation through activation of guanylate cyclase and generation of intracellular cyclic GMP (Saxena *et al*., 2021). Interruption of NO production via inhibition of constitutively expressed endothelial NO synthase (eNOS) causes BP elevation and development of hypertension in animals and humans (Brouwsers *et al*., 2021). Studies to evaluate NO activity in humans have demonstrated decreased whole body production of NO in patients with hypertension compared with normotensive controls (Liu *et al*., 2021). Endothelial cells also secrete a variety of other vasoregulatory substances, including vasodilators, such as prostacyclin and endothelium-derived hyperpolarizing factors, and vasoconstrictors, such as endothelin 1 (ET1), locally generated angiotensin II and the prostanoids thromboxane A2 and prostaglandin A2 (Saxena *et al*., 2021).

Endothelin is a potent vasoconstrictor that activates ET1 receptor (ETA) in vascular smooth muscle (Gentile *et al*., 2022). Other vasodilating substances secreted by a variety of cell types, such as calcitonin gene-related peptides, adrenomedullin and substance P, act primarily through increases in NO release from endothelial cells (Serrano-Ponz *et al*., 2016). The glucose-regulating gut hormone glucagon-like peptide 1 also has vasodilating properties (Javed *et al*., 2018). The balance between these factors, along with NO and ET1, determines the final effect of the endothelium on vascular tone (Gentile *et al*., 2022). Circulating ET1 levels are not consistently increased in hypertension, but there is a trend towards increased sensitivity to the vaso-constrictor and hypertensive effects of ET1 in individuals with hypertension (Lucero *et*

al., 2022). ETA antagonists attenuate or abolish hypertension in a variety of experimental models and are effective in lowering BP in humans (Lucero *et al*., 2022). Endothelial dysfunction plays a seminal part in the pathogenesis of hypertension. Normotensive offspring of parents with hypertension often have impaired endothelium-dependent vasodilation, which implies a genetic component in the development of endothelial dysfunction (Saxena *et al*., 2018).

Endothelial dysfunction in the setting of chronic hypertension is related to a combination of direct pressure-induced injury and increased oxidative stress. Several enzyme systems, including NADPH oxidase, xanthine oxidase and cyclooxygenase, as well as decreased activity of superoxide dismutase, generate reactive oxygen species (Saxena *et al*., 2019). Excess superoxide anions bind to NO, decreasing NO bioavailability and generating the pro-inflammatory oxidant peroxynitrite (Brouwser *et al*., 2021). Decreased NO bioavailability is the central factor that links oxidative stress to endothelial dysfunction and hypertension (Saxena *et al*., 2019). Individuals who are salt-sensitive might be very sensitive to the haemodynamic stress of increased blood volume, leading to overproduction of TGF-β and oxidative stress and limiting bioavailable NO (Uruski *et al*., 2025). Angiotensin II, along with other factors, including cyclic vascular stretch as a result of BP changes, ET1, uric acid, systemic inflammation, noradrenaline, free fatty acids and tobacco smoking, increases NADPH oxidase activity and plays a central part in the generation of oxidative stress in hypertension (Lucero *et al*., 2022).

Sympathetic nervous system (SNS)

Baroreceptors and mechanoreceptors are house housed in various locations in arterial tree with specific function to sense pressure changes in the circulatory system., a key

place being the carotid sinus (Pijacka *et al.*, 2016). When this artery is stretched by elevated blood pressure, nerve bundles projecting from the baroreceptors in the carotid sinus send messages to the brain to reduce sympathetic outflow of nerve impulses (nerve traffic) and, thereby, Blood pressure (De Leeuw *et al.*, 2017). The SNS is generally more activated in persons with hypertension than in normotensive individuals (Sievers and Eckardt, 2019). SNS activity is also greater in individuals with obesity, in men than in women, in younger than in older persons and in those with advanced kidney disease (Oparil *et al.*, 2018). Many patients with hypertension are in a state of autonomic imbalance with increased sympathetic activity and decreased parasympathetic activity (Sievers and Eckardt, 2019). SNS hyperactivity is relevant to both the generation and maintenance of hypertension (figure 4). Studies in humans have also identified markers (such as increased systemic catecholamine spillover (the amount of catecholamines released from sympathetic nerves innervating blood vessels that enter the bloodstream) and neural nerve activity assessed by microneurography) of sympathetic overactivity in normotensive individuals with a family history of hypertension (Grassi *et al.*, 2015).

Among patients with hypertension, increasing severity of hypertension is associated with increasing levels of sympathetic activity measured by microneurography (Kim, 2024). Plasma catecholamine levels, microneurographic recordings and systemic catecholamine spillover studies have provided evidence of increased sympathetic activity in patients with hypertension who have obesity, in those with the metabolic syndrome and in those whose hypertension is complicated by heart failure or kidney disease (Ziegler and Milic, 2017). The importance of the SNS in the pathogenesis of hypertension has been defined in a variety of experimental models (Oparil *et al.*, 2018).

Models of obesity-related hypertension demonstrate that increased renal sympathetic nerve activity and its attendant increase in renal sodium reabsorption are key factors in the maintenance of sustained hypertension (Gentile *et al*., 2022). In another animal model, rats that received daily infusions of phenylephrine for 8 weeks developed hypertension during the infusions; their BP normalized under a low-salt diet after discontinuation of phenylephrine, but once rechallenged with a high salt diet, the animals became hypertensive again (Feng *et al*., 2017).

The degree of BP elevation on the high-salt diet was directly related to the degree of renal tubulo-interstitial fibrosis and decrease in glomerular filtration rate, suggesting that catecholamine-induced hypertension causes renal interstitial injury and a salt-sensitive phenotype that persists even after sympathetic overactivity is no longer present (Li *et al*., 2017). In addition, increased SNS activity results in α-1 adrenergic receptor-mediated endothelial dysfunction, vasoconstriction, vascular smooth muscle proliferation and increased arterial stiffness, which contribute to the development and maintenance of hypertension (Rust and Ekmekcioglu, 2016). Finally, there is evidence that sympathetic overactivity enhances salt sensitivity owing to a reduction in activity of *WNK4*, encoding serine/threonine kinase WNK4, which inhibits the thiazide-sensitive Na-Cl cotransporter, resulting in increased distal tubular sodium retention (Brouwser *et al*., 2021).

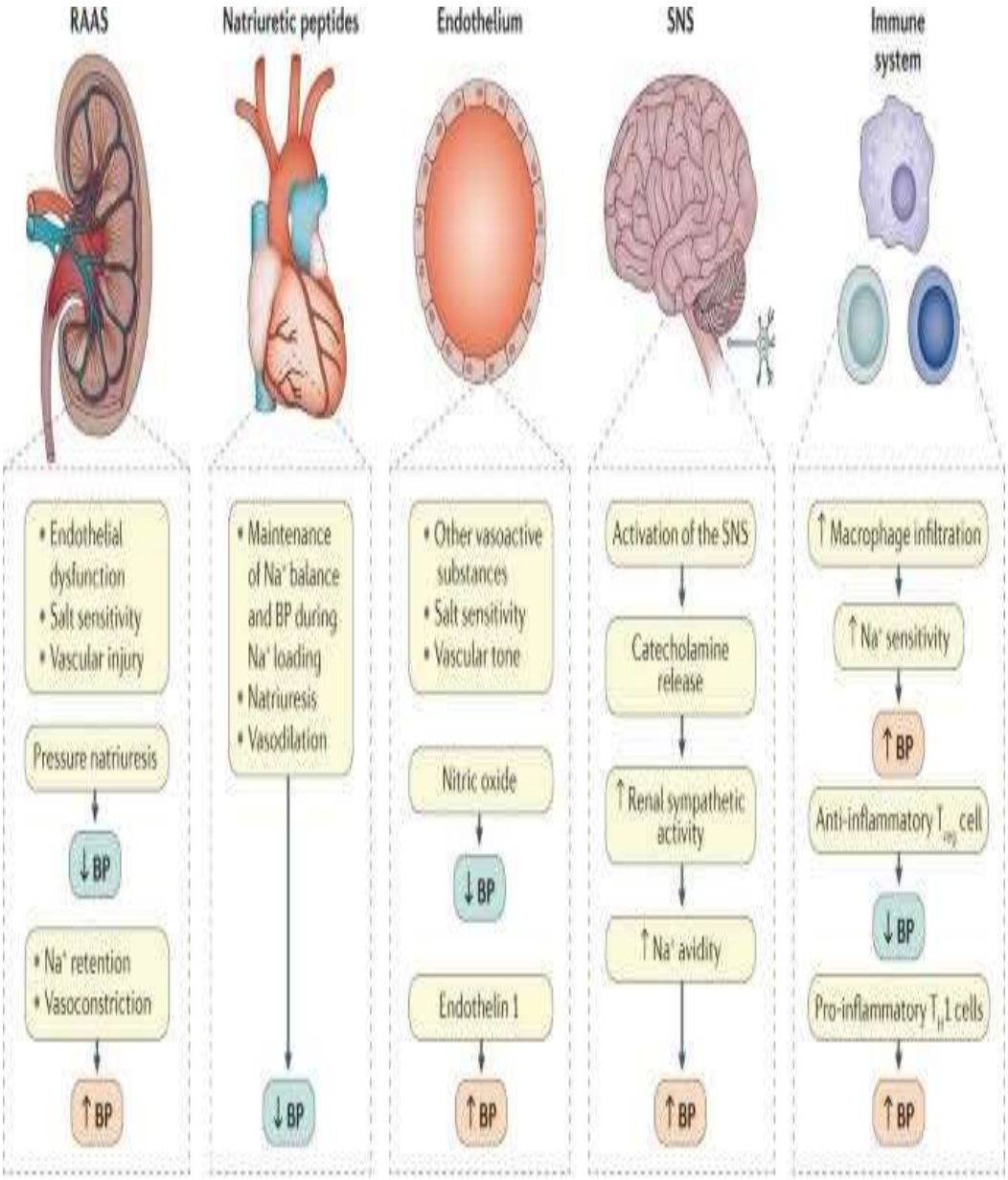


Figure 4: **The major neuroendocrine systems involved in the regulation of blood pressure.** Neurohumoral, immune and organ systems involved in the maintenance of blood pressure (BP). Na+ , sodium; RAAS, renin–angiotensin–aldosterone system; SNS, sympathetic nervous system; Treg, regulatory T. (Adapted from Oparil *et al*., 2018)

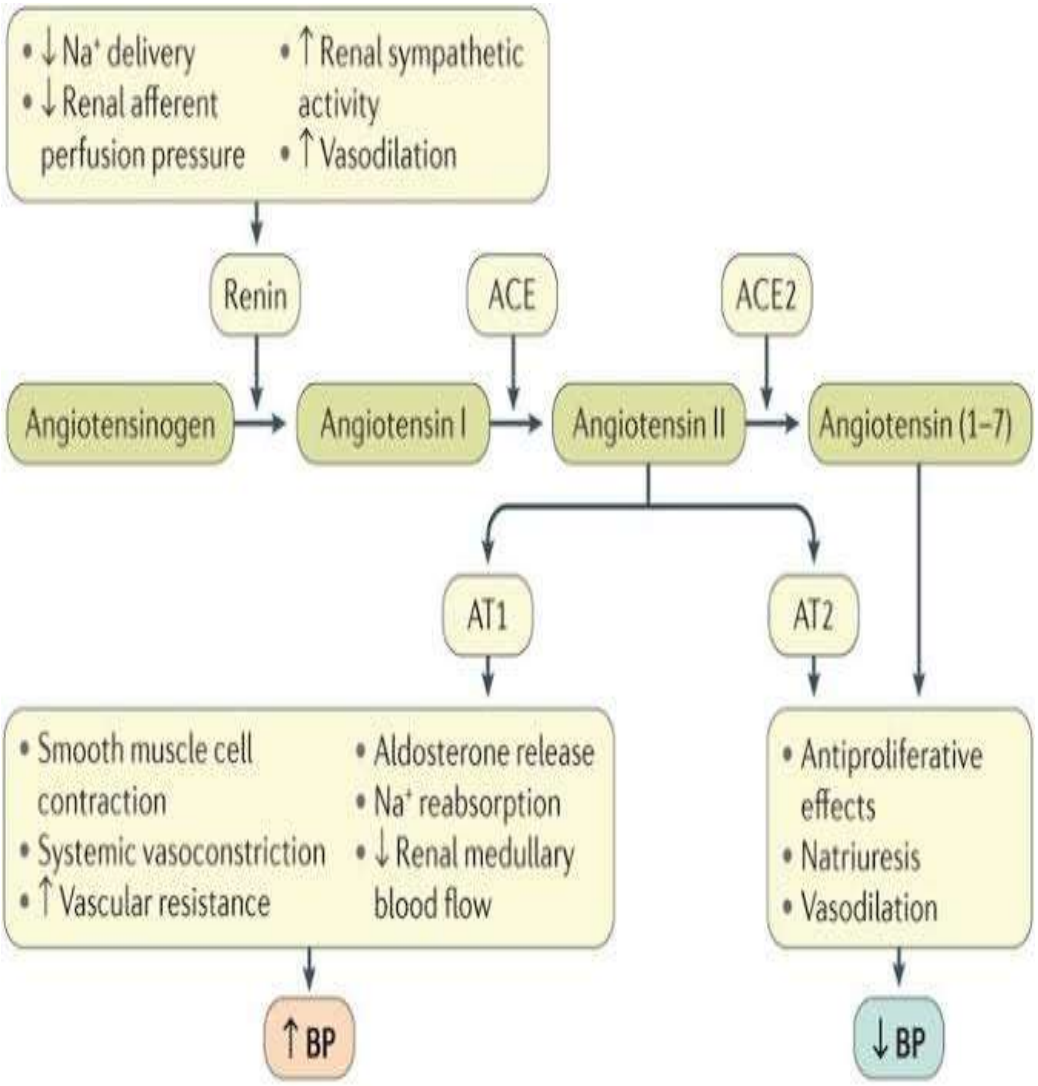


Figure 5: **Role of the renin–angiotensin–aldosterone system in the regulation of blood pressure** (Adapted from Oparil *et al*., 2018)

2.1.6 PREVENTION OF HYPERTENSION

In most countries such as Nigeria, there is a strong tendency for blood pressure, especially systolic blood pressure, and the prevalence of Hypertension to increase progressively from childhood until late adult life (Whelton, 2015). However, research have indicated that isolated societies (rural areas) that have limited contact with the outside world (Oparil *et al*., 2018) indicate that high blood pressure is not an inevitable consequence of ageing and that the blood pressure is associated with local migration related to changes in diet, decreased physical activity and consumption of alcohol (Junior, 2024). These underscore the propelling force and effort to prevent high blood pressure in settings where an age-related increase in BP is common.

Lifestyle changes

Various non-pharmacological interventions and approach have been investigated to be effective in lowering blood pressure and prevent Hypertension (Falkner and Lurbe, 2020). The most effective interventions are effort towards weight loss, reduction in sodium intake, increased potassium intake (Falkner and Lurbe, 2020), increased physical activity, reduced consumption of alcohol (Roerecke *et al*., 2017) and diets, such as the dietary approaches to stop hypertension (DASH) diet that combine several elements that favourably affect blood pressure (Whelton *et al*., 2018). The DASH diet is especially successful when combined with other effective BP lowering interventions, such as a reduced intake of dietary sodium (Carey *et al*., 2018; Kozol-Kozakowska *et al*., 2024). Lifestyle changes are the best way for the individual to implement these interventions. Even small improvements in an individual's lifestyle can be valuable. Public health interventions focused on dietary improvements and increases in physical activity that are known to lower BP provide the basis for population-wide strategies (Oparil *et al*., 2018). Low-dose pharmacological therapy has also been effective in

lowering BP and preventing hypertension in three randomized controlled trials conducted in adults with high normal blood pressure (Fuchs *et al*., 2016).

2.2.7 TREATMENT OF HYPERTENSION

Anti-hypertensive pharmcotherapy has evolved over several decades, driven by the discovery and development of various medication classes and large-scale outcome trials proving their benefits on CVD morbidity and mortality (Upadhya *et al*., 2022). Typically, antihypertensive pharmacotherapy begins with first-line antihypertensive medications either in monotherapy or in combination (Carrey *et al*., 2022). Combination therapy might be preferable in patients with higher levels of pre-treatment blood pressure. First-line antihypertensive medications include ACE inhibitors, angiotensin II receptor blockers (also known as sartans), dihydropyridine calcium-channel blockers and thiazide diuretics (Verdecchia *et al*., 2022). β-Adrenoreceptor blockers are also indicated in patients with heart failure with reduced left ventricular ejection fraction or post-myocardial infarction, and some guidelines recommend β-adrenoreceptor blockers as first-line antihypertensive medications (Saxena *et al*., 2021). The choice should be based on individual efficacy and tolerability (Javed *et al*., 2018). Further, in specific clinical situations, for example, hypertension in pregnant women, other medications such as α-methyldopa (an agonist of α-adrenoreceptors in the central nervous system that inhibits the SNS) or labetalol (an α-β-adrenergic antagonist) are preferable, whereas some first-line antihypertensives, for example, ACE inhibitors and angiotensin II receptor blockers, are contraindicated because of increased risk of renal teratogenicity (Balahura *et al*., 2023; Gallo and Savola, 2024).

2.2 THE KIDNEY

2.2.1 ANATOMY AND PHYSIOLOGY OF THE KIDNEY

The kidneys play an essential role in preserving homeostasis of the body's internal environment, including regulation of water, electrolyte, nitrogen, and acid–base balances (Gantsova *et al*., 2024). They also control the red blood cell production and blood pressure (Kim *et al*., 2015). Impaired renal function is commonly observed in clinical practice and is often associated with the use of drugs (Mahadevan, 2019). Human kidneys contain around 1 million nephrons (Bhaskar and Oommen, 2018). A nephron is composed of different subunits and includes the glomerulus, proximal tubule, loop of Henle, distal tubule, and the collecting duct (Klatte *et al*., 2015) (Figure 6). All sub units contribute to the excretory function of the kidney in three steps: glomerular filtration, tubular reabsorption, and tubular secretion (Thompson and Joy, 2022). During glomerular filtration (Figure 6), blood plasma is filtered in the glomerulus, a bundle of porous capillaries lined by a membrane and specialized epithelial cells, that allows solutes and waste, including drugs and their metabolites, and water to pass through while ensuring larger substances, such as blood cells and proteins, remain in the circulatory system (Kim *et al*., 2015). Protein-bound molecules, including drugs, are eliminated by proximal tubular secretion via a well-coordinated process of uptake by the tubular cells at the blood-facing basolateral site and secretion into the tubular lumen (Bhaskar and Oommen, 2018).

Tubular reabsorption begins as soon as the filtrate enters the lumen of the proximal tubule, and involves the reabsorption of organic nutrients, such as glucose, and hormonal-regulated reabsorption of ions coupled with passive water reabsorption (Feher, 2017). Megalin and cubilin receptors at the apical membrane are responsible for endocytosis-mediated re-uptake of filtered low-molecular-weight proteins, such as

β2-microglobulin (Eshbach and Weisz, 2017). As the filtrate travels along the nephron, some drugs, hydrogen ions, and ammonia are secreted into the collecting tubule (Feher, 2017). Even though the main function of the kidney is to excrete waste products from the bloodstream, it is important to mention that the kidney is also a major endocrine organ (Haussler *et al*., 2016). Five very important hormones/enzymes are produced by the kidney, viz, 1,25-dihydroxyvitamin D3, erythropoietin, renin, Klotho, and kallikrein (Haussler *et al*., 2016). Calcitriol, 1,25-dihydroxyvitamin D3, is activated in the proximal tubule and acts in the reabsorption of calcium, but it is also involved in bone health and in the regulation of parathyroid function (Sands and Verlander, 2018). Erythropoietin is produced by peritubular capillary endothelial cells in the proximal tubule, and acts by stimulating the production of red blood cells in the bone marrow (Buffi *et al*., 2018). Renin is secreted by granular cells of the juxtaglomerular apparatus. This enzyme also known as angiotensinogenase is the key factor of the renin–angiotensin system (RAS) that leads to the production of the potent vaso-constrictor angiotensin controlling blood pressure (Roy *et al*., 2015). Klotho is synthesized and secreted by the distal tubule. Similar to calcitriol, Klotho is involved in the calcium and phosphate homeostasis (Kim *et al*., 2015). Kallikrein of the renal kallikrein–kinin system is found in the distal tubule, and is involved in the regulation of blood pressure (Kim, 2024).

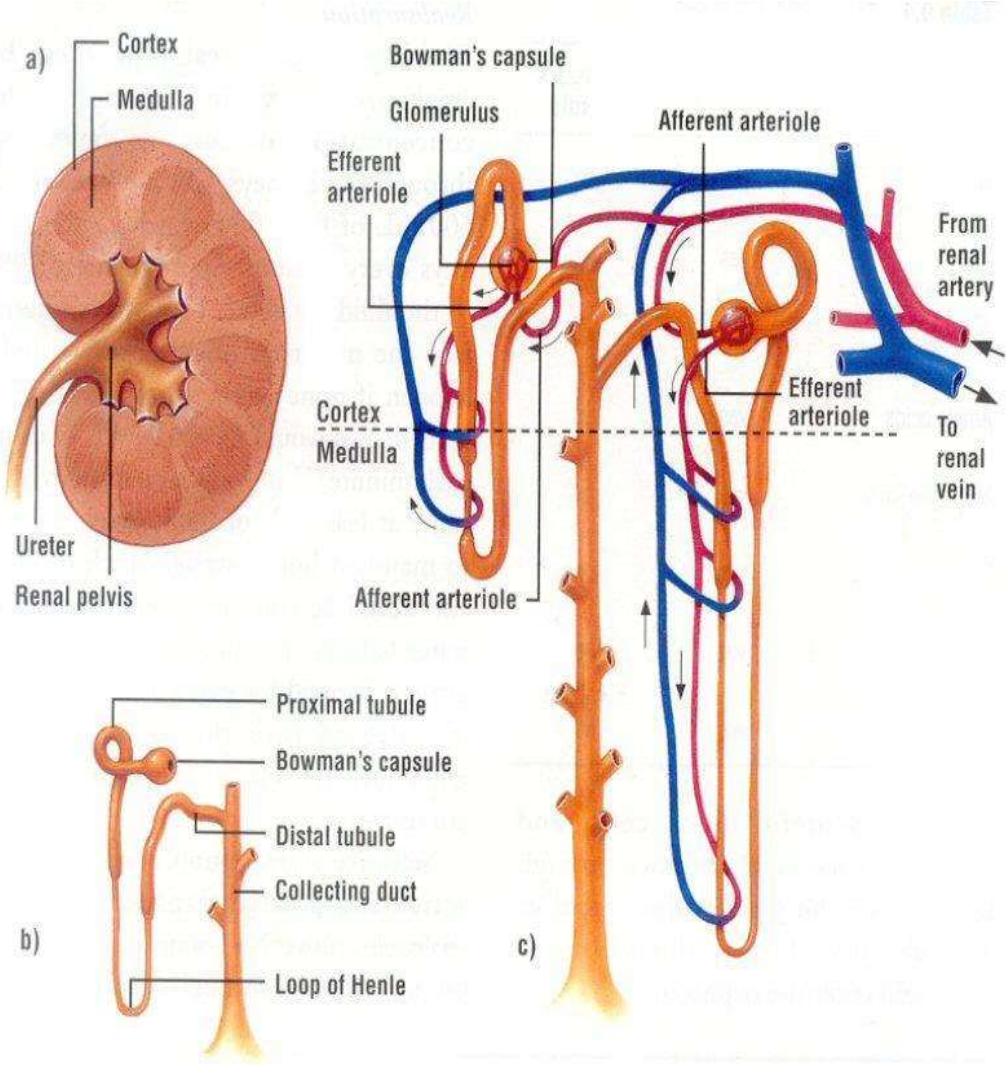


Figure 6. Anatomical structure of the kidney. (A) Macroscopical representation of kidneys and their connections with the vascular system (B) The kidney is composed five different parts (C) Representation of the different segments of the nephron (adapted from Faria *et al*., 2019)

2.2 HYPERTENSION AND ITS EFFECTS ON RENAL FUNCTION

2.2.1 HYPERTENSIVE NEPHROPATHY: CLINICAL AND HISTOPATHOLOGICAL CHARACTERISTICS

Hypertensive nephropathy, also known as “hypertensive nephrosclerosis”, is traditionally characterized by a combination of pathological changes of the pre- and intra-glomerular microvasculature and the tubulointerstitium (Sievers and Eckardt, 2019). Histopathology can hardly distinguish whether arterial hypertension is the primary cause of kidney dysfunction or whether increased blood pressure occurs as a comorbidity, which drives CKD progression (Kim, 2024). Thus, the term hypertensive nephropathy summarizes both conditions. The severity of blood pressure elevation often correlates with the degree of renal damage (Lucero *et al*., 2022). In many cases, hypertensive nephrosclerosis shows a slow progression, which is historically classified as “benign nephrosclerosis”. In contrast, accelerated nephrosclerosis, histopathologically characterized by fibrinoid necrosis and/or myointimal cell proliferation, is classified as “malignant nephrosclerosis” and frequently leads to ESRD (Costantino *et al*., 2021).

Hypertension-induced kidneydamage involves different cell types and anatomical structures in the kidney, including the vasculature, glomeruli, tubulointerstitium, and immune cells (Scheppach *et al*., 2018). The muscular arteries and arterioles of the kidney parenchyma show progressive intimal thickening during aging, but besides age this process correlates with arterial hypertension (Liang *et al*., 2016). The thickening is caused by collagen deposition and spreading of elastic fibers and myofibroblasts, and ultimately leads to more pulsatile blood flow in kidney arterioles (Liang *et al*., 2016). Another histopathological characteristic of hypertensive nephrosclerosis is arteriosclerosis of the afferent arterioles, also referred to as “afferent arteriolar

hyalinosis". These typical hyaline deposits are the consequence of a pathogenetic cascade of atrophy of vascular smooth muscle cells, increased endothelial leakiness and plasma protein extravasation, leading to sub-endothelial protein accumulation (Thomas *et al*., 2017). Although this process is associated with hypertension, to some extent, it occurs in all aging kidneys (Scheppach *et al*., 2018).

The glomerular involvement is heterogeneous; there is a side-by-side normal morphology, ischemic, obliterated glomeruli, with collapsed capillaries and focal-segmental-glomerular sclerosis-(FSGS)-like lesions, with partially sclerotic glomerular adhesions. Another hallmark of hypertensive kidney injury is tubular atrophy, accompanied by interstitial fibrosis. Following a loss of functional nephrons, the surviving nephrons initially maintain total kidney function, but the concomitant hemodynamic adaptations results in an oxygen supply-demand mismatch and ultimately tubulointerstitial hypoxia (Thomas *et al*., 2017). Tubulointerstitial hypoxia presumably contributes to the progression of tubular damage and renal functional impairment (Venkatachalam *et al*., 2015; Fu *et al*., 2016). This relative hypoxia is further aggravated by impaired oxygen delivery to the kidneys during hypertension, due to vasoconstriction hormones, including components of the RAAS, prostaglandins, and endothelin (Fu *et al*., 2016). During the course of CKD, the loss of peritubular capillaries further aggravates tubulointerstitial hypoxia and damage. Hypoxic conditions trigger mitochondrial dysfunction (Thomas *et al*., 2017) and can activate the transcription factor hypoxia-inducible factor (HIF) (Kim, 2024). Besides the characteristic vascular adaptations and glomerular pathology, kidney histology of hypertensive nephrosclerosis may also show trans-differentiation and apoptosis of

tubular cells, increased peritubular fibrosis, fibroblasts proliferation, and increased interstitial inflammation (Sievers and Echardt, 2019).

2.3 EMPIRICAL STUDIES ON RENAL FUNCTION IN HYPERTENSIVE POPULATIONS AS WELL AS CORRELATION

Kintu *et al*. (2023) study "The causal effects of lipid traits on kidney function in Africans: bidirectional and multivariable Mendelian-randomization study". This study used Mendelian randomization to investigate the effect of lipid traits on eGFR. It found significant causal associations between higher LDL-C and total cholesterol with higher eGFR levels, suggesting a U-shaped relationship. Ukibe *et al*. (2022) studi on "Evidence of Risk Factors Associated with Autosomal Dominant Polycystic Kidney Disease in Newly Diagnosed Adult Hypertensive Patients in NAUTH Nnewi, Nigeria" showed that hypertensive subjects had significantly higher serum creatinine, urea, and lower eGFR compared to normotensive controls. Additionally, 46.3% of hypertensive subjects had elevated urea/creatinine levels, and 30% showed multiple signs of ADPKD.

According to Gbadegesin *et al*. (2019) study on renal profiling in newly diagnosed hypertensives in Urban population in Nigeria among two hundred and fifty newly diagnosed hypertensive Nigerians recruited from two contiguous hospitals in an urban setting in south western Nigeria. Another group of two hundred and fifty apparently healthy age and sex matched normotensive Nigerians in the same community were recruited as controls. Result indicated that Seventy (28%) of the newly diagnosed hypertensives had estimated glomerular filtration rate of less than 60ml/min, while 42.4% and 18.8% of the subjects and the controls had microalbuminuria respectively. The newly diagnosed hypertensives had significantly higher prevalence of analgesic

use (86.4% versus 41.6%, $p < 0.001$), alcohol consumption (20.8% versus 12%, $p = 0.008$), use of canned salted food (18.8% versus 8.4%, $p= 0.001$) and central obesity (36.1% versus 26.8%, $p= 0.025$) compared to controls. Gbadegesin *et al*. Concluded that there is a significant occurrence of modifiable renal risk factors in newly diagnosed hypertensives and this offers a platform for instituting preventive strategies in the community.

Nwachukwu *et al*. (2016) study on pattern of renal impairment among hypertensive subjects in Umuahia, South East, Nigeria. A cross-sectional study involving 262 subjects comprising equal number of hypertensive and non-hypertensive was used. Result showed the GFR in hypertensive group was 87.4±30.2 ml/min/1.73 m2 compared to 99.9 ±32.3 ml/min/1.73 m2 in the non-hypertensive. In the hypertensive group, 30.5, 29.0 and 0.8% had mild, moderate and severe renal impairment respectively whereas in the non-hypertensive group, the values were 28.2, 14.5 and 0.8% respectively. The prevalence of CKD in hypertensive subjects was 29.8% while that in the non-hypertensive was 15.3%. 55.6% of male hypertensive subjects had mild to moderate renal impairment compared to 23.5% in the non-hypertensive group; the difference between hypertensive and non-hypertensive in females was not statistically significant. More females had CKD than their male counterparts. Hypertension might have increased incidence of renal impairment and prevalence of CKD in Nigeria.

The correlation between blood pressure and renal function in Nigeria has been extensively studied, revealing significant insights into the interplay between these two critical health parameters. According to Uwah *et al*., (2021) study on the assessment of arterial blood pressure and biochemical markers of renal function in young adults in Southern, Nigeria. The results showed that the mean systolic and diastolic blood

pressure were 132.50±4.16 mmHg and 84.36±4.35 mmHg, respectively. The mean glomerular filtration rate (GFR) was 64.56±3.28 mL/min/1.73m², with males having a higher GFR than females. The study indicated that the mean systolic and diastolic blood pressure were within the pre-hypertensive range, with mild to moderate derangements in renal function parameters such as glomerular filtration rate (GFR), serum electrolytes, urea, and creatinine levels. This study shows the importance of monitoring blood pressure and renal function even in apparently healthy young adults to prevent long-term complications.

Another study conducted in North Central, Nigeria evaluated blood pressure control and kidney disease markers in hypertensive patients. Among 1063 subjects, 39.7% had optimal BP control, while 12.2% had proteinuria and 19.9% had reduced eGFR. The study found that male sex and the use of renin-angiotensin-aldosterone system blocking medications were associated with proteinuria, while diabetes mellitus and treatment with more than two medications were linked to reduced eGFR. The conclusion was that a large proportion of hypertensive patients have poorly controlled BP and common kidney damage (Abene *et al*., 2020).

A bidirectional Mendelian randomization study provided evidence supporting the causal effects of kidney function on blood pressure. The study demonstrated that higher kidney function was associated with lower blood pressure, suggesting that preventing kidney function decline could reduce the public health burden of hypertension (Yu *et al*., 2020). Specifically, a one standard deviation increase in eGFR is associated with a significant decrease in both systolic and diastolic blood pressure. However, the reverse blood pressure affecting kidney function was not statistically significant (Yu *et al*., 2020). This finding shows the importance of maintaining kidney health to manage

blood pressure effectively. Adiele *et al*., (2023) study on Blood pressure trends in Children with Chronic Kidney Disease in Nigeria, Sub-Saharan African Region showed that Children with CKD had higher mean SBP (126.08mmHg) and DBP (78.96mmHg) compared to controls thus indicating a relationship between blood pressure and Renal function.

According to Sood *et al*., (2017) study on time varying association of individuals BP components with eGFR in Late-Stage CKD. This retrospective cohort study focused on patients with late-stage CKD and examined the associations of systolic BP, diastolic BP, and pulse pressure with changes in eGFR. The study found that extremes of systolic BP (<105 or >170) and high diastolic BP (>90) were associated with a higher risk of eGFR decline by 30%. Pulse pressure was not significantly associated with eGFR decline. Staplin *et al*., (2022) carried out a study on "Determining the Relationship Between Blood Pressure, Kidney Function, and Chronic Kidney Disease: Insights From Genetic Epidemiology".Using genetic risk scores, this study found that higher genetically predicted BP was associated with higher odds of CKD and glomerular hyperfiltration. Each 10 mmHg increase in systolic BP and 5 mmHg increase in diastolic BP were associated with a 37% and 19% higher odds of CKD, respectively. The study supports a causal role of BP in decreased kidney function and albuminuria.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA AND SITE

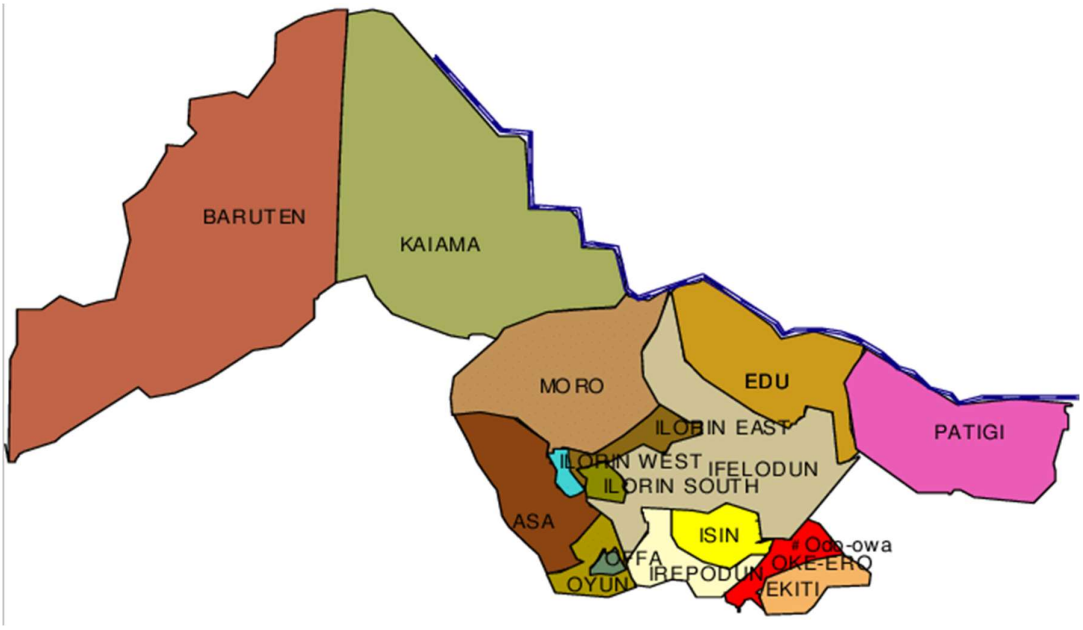


Figure 7: Map of Kwara State Showing Irepodu Local Government Area

The Research study was done at Thomas Adewumi University teaching hospital among Hypertensive patients attending Thomas Adewumi University teaching hospital Kwara State. Oko community is one of the major community in Irepodun Local Government area, Kwara State, North central geopolitical zone of Nigeria. The community is situated approximately 30Kilometers from Ilorin, the State Capital. The Oko Community is located on latitudes 8.43333ºN of the Equator and longitudes 4.58333ºE of the Greenwich Meridian and at an altitude of about 304m above the mean sea level. The primary language spoken in Oko community is Yoruba, with many residents also speaking English as a second language. The people of Oko community engage in Agriculture with farming being the main occupation. Additionally, there are small-scale businesses and trading activitities within the community. The community is also characterized by a hilly terrain and a warm climate with an average temperature of around 30^0C. the area experiences two main season: rainy and dry season. The community is also known for its scenic lanscape and natural beauty. Educational Institution is also found in the community such as Oko community secondary school, Thomas Adewumi University located in Oko-irese, Kwara State Education. Health Facility present in the community is majorly Oko primary health care centre.

3.2 STUDY POPULATION.

Samples was obtained from sub-population of Hypertensive subjects and Non-hypertensive subjects within the same age group attending

3.3 STUDY DESIGN

This was a prospective case-control study where random sampling technique was employed to enroll participants. Informed consent, Questionnaire, Blood pressure, Blood sample of 5millitres was obtained from both hypertensive and non-hypertensive subjects within the same age range and dispensed into Lithium Heparin anticoagulant

bottle. It was transported to the Laboratory and spun using Bucket Centrifuge to obtain plasma which was used to determine Serum creatinine and Urea.

3.4 INCLUSION AND EXCLUSION CRITERIA

3.4.1 INCLUSION CRITERIA FOR CASE

1. Age between 18-65years

2. Known Hypertensive patients (systolic BP ≥140mmHg or diastolic BP ≥90mmHg) or currently on anti-hypertensive treatment.

3. Those who met the above criteria and agreed to participate in the study by signing the informed consent form was recruited.

3.4.2 EXCLUSION CRITERIA FOR CASE

1. Patients with known diagnosis of Chronic Kidney disease (KCD)

2. Patients with Comorbities patients such as on treatment including glucocorticoids, anti-coagulants or antiplatelet drugs, or presenting with febrile illness were excluded from the study (this is to prevent obtaining a wrong result by interference of inflammation etc).

3. Parents not willing to give written informed consent.

3.4.3 INCLUSION CRITERIA FOR CONTROL

1. Age: 18-65years

2. Participants willing to give written informed consent.

3.4.4 EXCLUSION CRITERIA FOR CONTROL

1. Participants outside age range of 18-65 years was excluded from the study for both gender

2. Participants having any inflammatory condition or disease that can affect Parameters to be obtained was excluded from the study

3.5 DURATION OF THE STUDY

This study was carried out over a period of 4 months from April to July 2025

3.6 SAMPLE SIZE DETERMINATION

Sample size calculation for comparison of independent mean was derived as follows:

$$N = \frac{2(Z_{\alpha/2}+Z_{\beta})^2 .\sigma^2}{(\mu_1 - \mu_0)^2}$$

Where; n= Required sample size for each group

$Z_{\alpha/2}$ = Z-score for the desired confidential level (typically 1.96 for 95% confidence)

Z_{β}= Z-score for the desired power (commonly 0.84 for 80% power).

$(\mu_1 - \mu_0)^2$ = Mean difference of renal function parameter in hypertensive and non-hypertensive group respectively (eGFR)

σ^2= estimated standard deviation of the renal parameter (e.g eGFR)

μ_1 =83.8ml/min/1.73m2, (Kao *et al*., 2020) σ =16.4

μ_2= 71.52ml/min/1.73m2 (Li *et al*., 2022)

imputing values into the formula above:

$$\frac{2(1.96 +0.84)^2 x(16.4)^2}{(83.8-71.52)^2}$$

$$= \frac{15.68 \text{ x } 268.96}{(12.28)^2}$$

$= 27.97 \approx 28$

Approximated to 28.

Thus, the minimum sample size for each study group is 28.

Hence: participants without hypertension (Apparently healthy individuals) = 28

participants with hypertension = 28

To further improve the power of the study, the sample size for each group was increased

Hence;

Participants without hypertension = 30

Participants with hypertension = 30

Total sample size for this study will be at least 60

3.7 SAMPLING TECHNIQUE

A sample random sampling technique method was used to recruit hypertensive patients attending Thomas Adewumi University teaching hospital, Kwara State. Subjects was selected using consecutive recruitment method to reduce bias. Invitees that consent after receiving study information was enrolled.

DATA COLLECTION TECHNIQUES (QUESTIONNAIRE ADMINISTRATION AND HISTORY TAKING)

Each participant was interviewed to obtain relevant demographic and clinical data with the use of a questionnaire. The questionnaire was administered to each participant by the researcher. Information on the subjects and their medical history including disease complications was retrieved from their case notes .

3.8 SPECIMEN COLLECTION AND STORAGE

5mls of venous blood was drawn from each subject after informed consent has been signed. This was done from an intravenous access (the antecubital vein) and under aseptic conditions with the use of a disposable vacutainer needle. The blood drawn was dispensed into Lithium heparin anticoagulated specimen bottles, separated and stored in Freezer at -36^0C until the day of analysis for estimation of creatinine and urea in case of delay in laboratory analysis. Transportation of Samples from collection site to the Laboratory was done strictly under cold chain using ice.

3.9 LABORATORY INVESTIGATIONS

Blood samples obtained from the subject was analyzed using Audicom Ion Selective electrode (ISE) for electrolyte, Ichem 525 Autoanalyzer for serum urea and creatinine using Agappe reagent product immediately after collection before deterioration sets in, while Estimated glomerular filtration rate was estimated using formula

3.9.1 DETERMINATION OF ELECTROLYTE

It was quantified using ion selective electrode

Principle

The ion-selective electrode (ISE) principle for electrolytes is based on the fact that each ion in solution carries a charge, and this charge can be detected by a specific electrode designed to respond selectively to that ion. An ideal I.S.E. consists of a thin membrane across which only the intended ion can be transported. The transport of ions from a high concentration to a low one through a selective binding with some sites within the membrane creates a potential difference.

Procedure

The ISE and reference electrode are to be rinsed with distilled water and then soaked in a solution of 3 M KCl for at least 15 minutes to equilibrate the electrodes. The ISE was calibrated using standard solutions of the target electrolyte, such as potassium, sodium, or calcium, in a concentration range that covers the expected plasma concentrations. The electrical potential generated by the ISE is recorded for each concentration, and a calibration curve is constructed by plotting the potential against the logarithm of the concentration. The plasma sample is diluted with an appropriate buffer to adjust the pH and ionic strength, and then placed in a cuvette containing the ISE and reference electrode. The electrical potential generated by the ISE is recorded, and the concentration of the target electrolyte is calculated using the calibration curve. The data

was analyzed using statistical methods. The results are reported in units of millimoles per liter (mmol/L) or milliequivalents per liter (mEq/L), depending on the laboratory's preference.

3.9.2 DETERMINATION OF SERUM UREA

It was estimated using Berthelot method

Principle: Urease enzyme hydrolyzes urea at 37°C to form ammonia and C02. The ammonia ion then reacts with a mixture of salicylate, sodium nitroprusside and hypochlorite to yield a blue-green chromophore (2,2-dicarboxy Indophenol) which is then read at 600nm.

Procedure: 0.02ml of sample and standard was added to 1ml of reagent 2 which was incubated for 10 minutes at room. Temperature. 1ml of Reagent 1 (Colour reagent) will be added to the mixture and was incubated for 10 minutes at room temperature.

TABLE 3.9.2: DETERMINATION OF SERUM UREA

Reagent	Blank	Standard	Test
Working reagent 2	1000ul	1000ul	1000ul
Standard	-	20ul	-
Serum sample		-	20ul
Mix and incubate for 10 minutes at Room temperature			
Colour reagent	1000ul	1000ul	1000ul
Mix and incubate for 10 minutes at Room temperature			
Distilled water	1000ul	1000ul	1000ul
Mix well and measure absorbance of sample and the standard against the reagent blank			

$$\text{Urea concentration (mg/dl)} = \frac{\text{Absorbance of sample}}{\text{Absorbance of Standard}} \times 40$$

3.9.3 DETERMINATION OF SERUM CREATININE

This was quantified using Jaffe slots method.

Principle: Creatinine reacts with picric acid in an alkaline medium (NaOH) to produce yellow-orange level colour compound and this change in absorbance is proportional to the creatinine concentration read at 505nm.

Procedure: Mix equal volume of creatinine base and creatinine dye to form working reagents. 0.1ml of sample and standard was added to 1ml of the working reagent. The mixture was read at 505nm after 60seconds of optical density (T_1) after the sample or standard addition. Exactly 60 seconds after the first reading, take the second reading (T_2).

Table 3.9.3: DETERMINATION OF SERUM CREATININE

Reagent	Standard	Test
Working reagent	1000ul	1000ul
Standard	100ul	-
Serum sample	-	100ul

3.9.4 DETERMINATION OF ESTIMATED GLOMERULAR FILTRATION RATE (eGFR)

The eGFR is calculated using a formula that includes the serum creatinine level, along with age, sex and race. The most widely used equations are:

CKD-EPI equation (Chronic Kidney Disease Epidemiology Collaboration)

STATEMENT OF CONFIDENTALITY OF DATA COLLECTED FROM THE SUBJECTS

All data was obtained anonymously and unlinked to participants' personal, health or treatment records. Therefore, participants was traceable from collected data or specimens.

3.10 DATA ANALYSIS

Data was analyzed using SPSS version 27.0 (Statistical Package for Social Sciences). The descriptive data obtained was presented in Tables, Bar chart and Mean ± standard deviation (SD). The Pearson chi-square test and multi-regression analysis was used for analytic assessment and the differences was considered to be statistically significant when the p-value obtained was <0.05.

3.11 ETHICAL ISSUES/CONSIDERATIONS

Ethical approval was obtained from Ministry of Health with ID ERC/MOH/2025/02/437. The study was conducted in accordance with the guidelines on obtaining informed consent from participants. Written consent was obtained from each participant’s parent or caregiver. Participants was informed about the objectives, benefits and procedure of the study and that participation in the study is voluntary, confidentiality is assured and any eligible participants can withdraw from the study at any time without adverse consequences.

CHAPTER FOUR

4.0 RESULTS

Table 4.1 Presents the comparison of mean blood pressure between hypertensive (n = 50) and non-hypertensive (n = 20) patients. The mean systolic blood pressure (SBP) was significantly higher in the hypertensive group (199 ± 35 mmHg) compared to the non-hypertensive group (114 ± 8 mmHg), with a t-value of 10.830 and a p-value < 0.001. Similarly, the mean diastolic blood pressure (DBP) was significantly elevated in hypertensives (128 ± 20 mmHg) versus non-hypertensives (72 ± 6 mmHg), with a t-value of 16.359 and a p-value < 0.001. These findings indicate a statistically significant difference in both SBP and DBP between the groups.

Table 4.1 Mean blood pressure between hypertensive and non-hypertensive patients

Characteristics	Hypertensive (N=50)	Non hypertensive (N=20)	T test	P value	Significant (p <0.05)
	Mean±SD	Mean±SD			
SBP (mmHg)	199±35	114±8	10.830	<0.001	Yes
DBP(mmHg)	128±20	72±6	16.359	<0.001	Yes

Keys:

SD -Standard deviation

SBP - Systolic blood pressure

DBP-Diastolic blood pressure

Table 4.2 Compares arithmetic indices - age, body mass index (BMI), and waist circumference-between hypertensive and non-hypertensive participants. Although hypertensive individuals had slightly lower mean age (40.92 ± 12.72 years) compared to non-hypertensives (46.50 ± 15.23 years), the difference was not statistically significant ($p = 0.122$). Similarly, differences in BMI (24.02 ± 7.38 vs. 22.88 ± 6.26; $p = 0.546$) and waist circumference (91.26 ± 14.86 cm vs. 87.20 ± 20.30 cm; $p = 0.357$) were not significant. Overall, none of the anthropometric parameters showed statistically significant differences between the two groups.

Table4.2 Arithmetic indices among hypertensive and non-hypertensive participants

Characteristics	Hypertensive(N=50)	Non hypertensive(N=20)	T test	P value	Significant ($p < 0.05$)
	Mean±SD	Mean±SD			
Age (years)	40.92±12.72	46.50±15.23	1.566	0.122	No
BMI	24.02±7.38	22.88±6.26	0.606	0.546	No
Waist circumference	91.26±14.86	87.20±20.30	0.927	0.357	No

Keys:

SD -Standard deviation

BMI- Body mass index

Table 4.3 Examines the effect of hypertension on serum sodium and potassium levels. While the mean serum sodium level was slightly higher in hypertensive patients (140.98 ± 1.28 mmol/L) compared to non-hypertensives (138.35 ± 0.78 mmol/L), this difference was not statistically significant ($p = 0.188$). In contrast, serum potassium levels were significantly higher in hypertensive individuals (4.21 ± 0.16 mmol/L) compared to non-hypertensives (3.40 ± 0.009 mmol/L), with a t-value of 3.106 and a p-value of 0.003. This suggests a statistically significant association between hypertension and elevated serum potassium levels.

Table 4. 3 Effect of hypertension on serum sodium and potassium levels

Characteristics	Hypertensive(N=50)	Non hypertensive(N=20)	T value	P value	Significant ($p < 0.05$)
	Mean±SD	Mean±SD			
Na (mmol/L)	140.98±1.28	138.35±0.78	1.330	0.188	No
K(mmol/L)	4.21±0.16	3.40±0.009	3.106	0.003	Yes

Keys:

SD -Standard deviation

Na- Sodium

K- Potassium

Table 4.4 Presents the impact of hypertension on selected renal function indices. Hypertensive patients showed significantly higher mean serum urea (6.62 ± 0.42 mmol/L) and creatinine levels (104.48 ± 4.43 mmol/L) compared to non-hypertensives (3.32 ± 0.14 mmol/L and 69.80 ± 2.92 mmol/L, respectively), with p-values < 0.001 for both. Conversely, the estimated glomerular filtration rate (eGFR) was significantly lower in hypertensives (81.57 ± 4.79 mL/min/1.73 m²) than in non-hypertensives (115.80 ± 6.21 mL/min/1.73 m²), also with a p-value < 0.001. These findings indicate that hypertension is associated with impaired renal function.

Table 4.4 Impact of hypertension on selected renal function indices

Characteristics	Hypertensive(N=50)	Non hypertensive(N=20)	T value	P value	Significant ($p < 0.05$)
	Mean±SD	Mean±SD			
Urea (mmol/L)	6.62±0.42	3.32±0.14	4.946	<0.001	Yes
Creatinine (mmol/L)	104.48±4.43	69.80±2.92	6.534	<0.001	Yes
eGFR	81.57±4.79	115.80±6.21	3.999	<0.001	Yes

Keys:

SD -Standard deviation

eGFR- Estimated glomerular filtration rate

Table 4.5 Presents a regression analysis evaluating the relationship between renal function parameters and blood pressure. Among the predictors, urea showed a negative but non-significant association with blood pressure (β = -5.870, p = 0.316), and creatinine displayed a positive but also non-significant relationship (β = 0.225, p = 0.271). Electrolytes, including sodium (β = -0.44, p = 0.945) and potassium (β = 1.434, p = 0.621), did not show significant associations with blood pressure. The model explained 57% of the variance in blood pressure (R^2 = 0.57), but the overall model was not statistically significant (ANOVA p = 0.561). These findings suggest no strong individual predictive relationship between the tested renal function markers and blood pressure in this analysis.

Table 4.5 Regression analysis showing the relationship between renal function parameters and blood pressure

Model	Standard coefficients	t	P value	R^2	ANOVA	Significant ($p < 0.05$)
urea(mmol/l)	-5.870	-0.842	0.316	0.57(57%)	0.561	No
creatinine(mmol/l)	0.225	10.152	0.271			No
sodium(Na)	-0.44	-0.471	0.945			No
potassium(K)	1.434	0.348	0.621			No

Keys:

Na- Sodium

K- Potassium

CHAPTER FIVE

5.0 DISCUSSION

Chronic hypertension damages renal microvasculature by affecting arterioles, nephrons, glomeruli leading to reduced perfusion, proteinuria, and a declining glomerular filtration rate. Conversely, impaired kidney function promotes sodium retention, volume overload, and heightened renin–angiotensin–aldosterone system (RAAS) activity, which elevates blood pressure. Hypertension has been identified as one of the major risk factors that contribute to the global increase in prevalence of CKD (Tedla et al., 2011). Uncontrolled hypertension can accelerate the development of CKD and may lead to End stage renal disease (ESRD), (De Bhailis *et al.,* 2021).

This study examined the relationship between renal function and hypertension and explored how age, body mass index (BMI), waist circumference, and serum electrolyte levels differ between hypertensive and non-hypertensive individuals.

In this study the mean systolic and diastolic blood pressure was significantly different between hypertensive and non hypertensive participants as those diagnosed with hypertension had markedly higher systolic and diastolic blood pressure. Several studies report that the average SBP and DBP are significantly higher in hypertensive patients compared to normotensive individuals. For instance, Zuin *et al.,* (2025) summarizes diagnostic thresholds as: SBP <140mmhg and DBP <90 for normotensive and >140mmHg and >90mmHg for SBP and DBP respectively for hypertensive patients, (Tsimploulis et al., 2017: Ku *et al*., 2021).

Based on age, BMI and waist circumference, there was no significant difference between the hypertensive participants and the normotensive participants but the BMI and waist circumference had a higher value In the hypertensive group, this could be as a result of the relatively small sample size used in this study. However, several reports document these parameters (age, BMI, waist circumference) as risk factors for both

hypertension and renal dysfunction, for instance as adiposity increases RAAS activity and sympathetic nervous system signaling. Although some propose a different opinion suggesting obese CKD patients may have better outcomes, but worthy of note is that most data support a direct link between higher BMI, increased visceral fat, and hypertension, (Chang *et al.,* 2018: Silke *et al.,* 2024)

Electrolyte handling is crucial in hypertension. Elevated serum or urinary sodium contributes to volume expansion, while potassium depletion can trigger RAAS activation. In this study there was no significant difference in the sodium levels relationship was observed in the potassium level. Several studies including one by Sherkati *et al*., (2025) link high sodium intake to higher hypertension risk (OR increased by 0.8% per unit sodium) but find no serum electrolyte differences, underscoring the importance of dietary intake over serum concentrations. Other previous studies indicate exchangeable sodium correlates positively with BP, while potassium correlates inversely, especially in younger hypertensive patients, (Park et al., 2016). The RAAS is central to this interplay. Renin release by juxtaglomerular cells triggers angiotensin II formation, inducing vasoconstriction, sodium retention, aldosterone secretion, and further renal injury

The sodium to potassium (Na/K) ratio is more strongly associated with increased blood pressure outcomes in hypertensive patients than sodium and potassium alone. Some studies such as Perez and Chang, (2014), Park *et al*. (2016) supports this, showing that a higher Na/K ratio correlates with elevated blood pressure and hypertension risks. Hypertensive patients benefits more from increased potassium intake, which promotes natriuresis(sodium excretion) and reduces vascular resistance . A 1000 mg/day increase in potassium excretion was associated with a 3.07 mmHg reduction in SBP in hypertensive groups, (Du *et al.,* 2021). Normotensive patients may not exhibit the same

blood pressure lowering response to potassium, as their renal and vascular systems are less sensitive to electrolyte imbalances, (Perez and Chang, 2014).

This study examined the urea, creatinine and estimated glomerular filtration rates (eGFR) between hypertensive and normotensive patients, our study revealed a significant difference in the urea, creatinine and eGFR as hypertensive patients exhibited a markedly higher values compared to their normotensive counterparts. A higher values indicares reduced or impaired kidney function and this is supported by several research such as the one presented by Hustapea *et al.,* (2021), their study revelaed a positive correlation between SBP and urea and creatinine. Elevated urea and creatinine are markers of kidney stress due to hypertension induced vascular damage and reduced renal perfusion, normotensive patients typically exhibit lower urea and creatinine levels reflecting preserved kidney function. Also, hypertensive pateints often show faster eGFR decline over time, in the ARIC study(Yu et al., 2019), hypertensives had an annual eGFR decline of -0.15 to -0.50 Ml/min/1.73 m^2 vs -0.11 in normotensives.

5.1 CONCLUSION

Our results highlight the complex interplay between hypertension, kidney function, obesity, and electrolyte balance. These findings emphasize the need for comprehensive management of hypertensive patients, focusing not only on blood pressure control but also on lifestyle interventions targeting weight reduction and dietary sodium and potassium intake.

5.2 RECOMMENDATION

Given the multifactorial nature of hypertension-related renal dysfunction, future studies should use longitudinal designs and adjust for medication, sex, and comorbidities to further provide the relationship between hypertension and renal damage

There is the need to create public awareness by appropriate government agencies and organizations about hypertension and CKD in our environment and develop strategies that will reduce their prevalence. More studies on CKD in different risk populations are recommended.

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